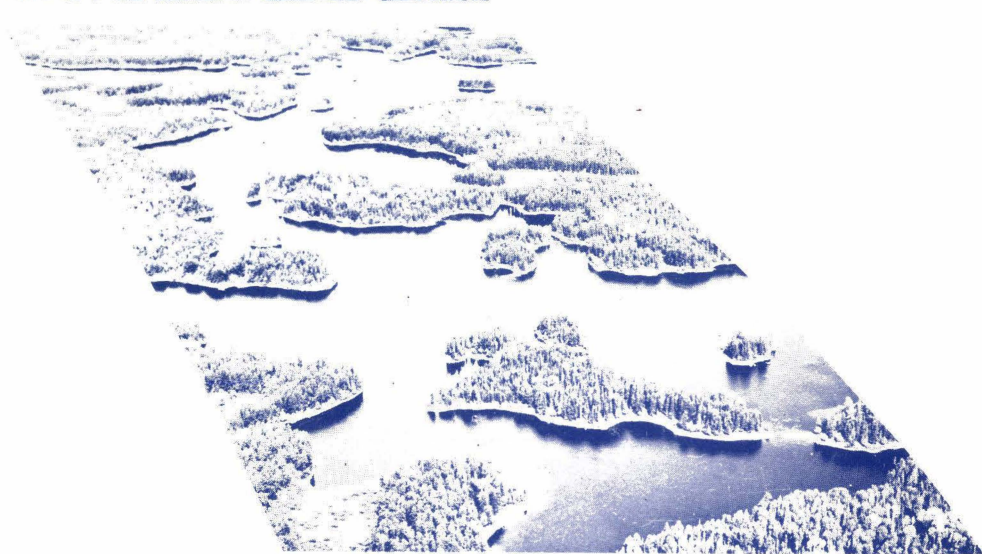


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A Glimpse of Research in the Lake States



September 1963

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EXPERIMENT STATION



Tour of the Lake States

September 30 -- October 4, 1963

Prepared for the
Forestry Research Advisory Committee
U.S. Department of Agriculture

Agricultural Research Advisory Committee
U.S. Department of Agriculture

By the
Lake States Forest Experiment Station
Forest Service, U.S. Department of Agriculture
St. Paul, Minnesota



U. S. FOREST SERVICE

Research Program at the Lake States Forest Experiment Station

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

M. B. Dickerman, Director,
Lake States Forest
Experiment Station

We welcome the first meeting of Secretary Freeman's Forestry Research Advisory Committee at the Lake States Forest Experiment Station, and we are particularly pleased to have the National Agricultural Research Advisory Committee with us for part of the program. We are hoping that you will take home with you not only an understanding of our more important research problems, but also the memory of a pleasant visit and accommodating hosts.

The Lake States is one of the distinctive forest regions. With about one-eighth of the commercial forests of the United States, it has some distinctive problems. No forest region in the United States has been cut over as rapidly and burned over so extensively. Most of the original forest was removed in a period of 30 years and much of the land most suited to forestry was converted to agriculture.

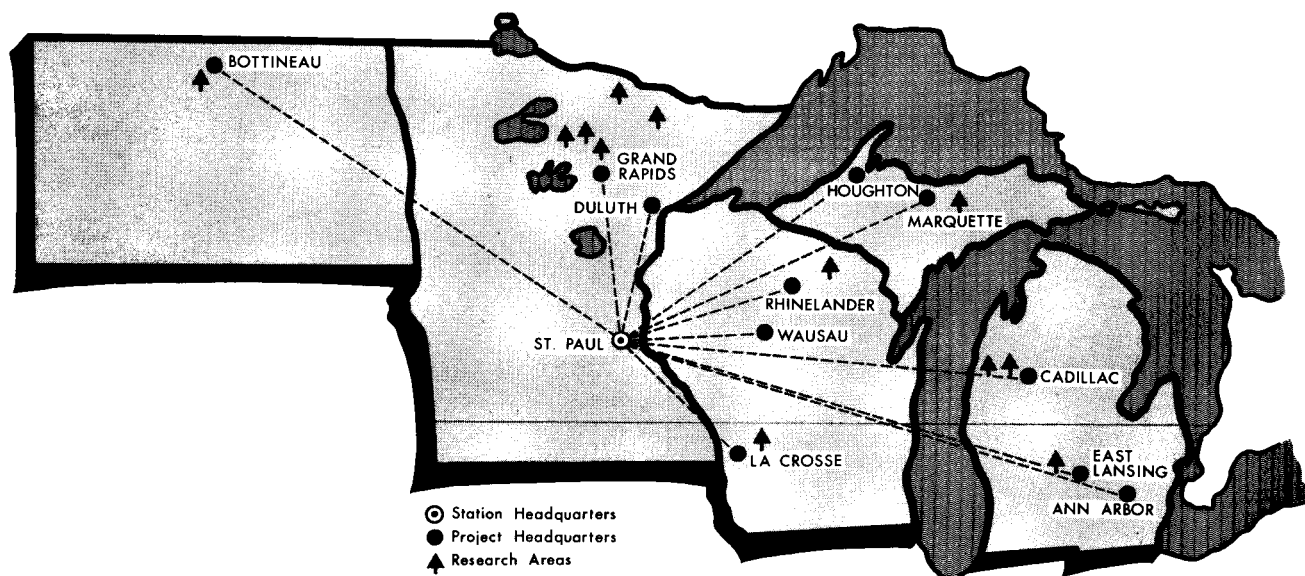
The new forest which has developed is characterized by large areas of low-

quality timber, limited stocking and a need for much planting. These factors coupled with depletion of ore reserves and a declining agriculture brought about rising unemployment, increasing outmigration, and low income.

But there is also much to give optimism. Timber volume is increasing, effective private and public forestry programs are accelerating, and other forest uses, such as recreation, are more and more contributing to income. In the next 20 years, there will be many opportunities for new forest industries. We look forward to a substantial strengthening of the total economy of the region.

In the short time available, we will show you a few of our forestry research activities in this area, and we will describe some of our work in the other states. You will, we believe, get a broad idea of some of our problems and what we are doing.

Today's tour will be conducted by Carl Arbogast, our forest management project leader at Marquette. He will be assisted by other project leaders and staff members.



Territory of the Lake States Forest Experiment Station

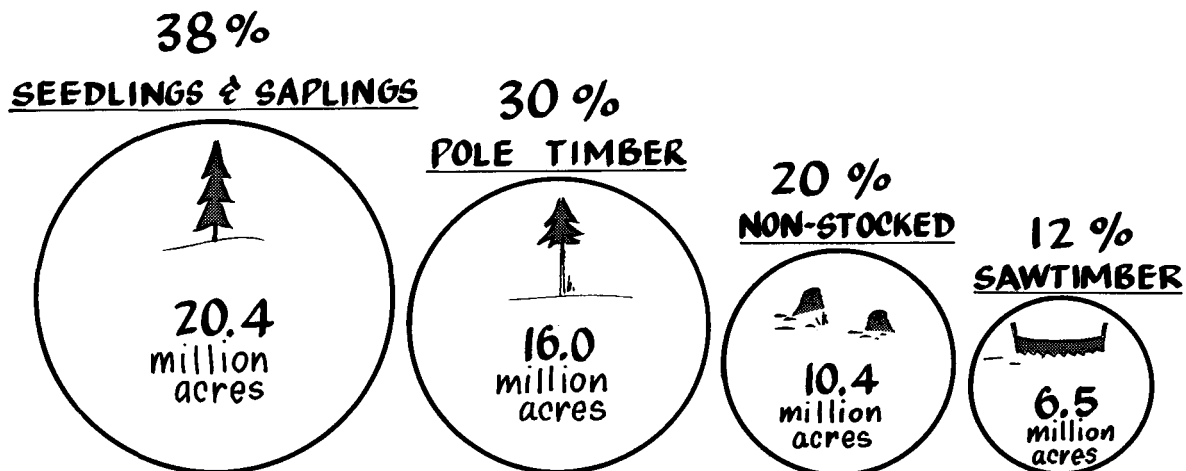
Station Headquarters -- St. Paul, Minnesota

<u>Field Location</u>	<u>Unit</u>
North Dakota	
Bottineau	Shelterbelt Laboratory
Minnesota	
Duluth	Field Headquarters
Grand Rapids	Northern Conifer Laboratory
Wisconsin	
La Crosse	Field Headquarters
Rhinelanders	Institute of Forest Genetics
Wausau	Field Headquarters
Michigan	
Ann Arbor	Field Headquarters
Cadillac	Field Headquarters
Houghton	Field Headquarters
East Lansing	Field Headquarters
Marquette	Northern Hardwoods Laboratory

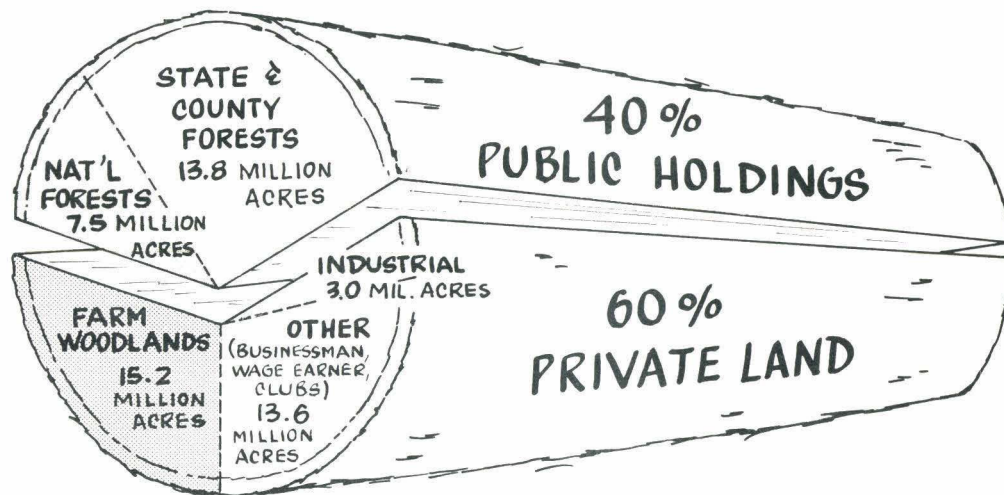
**1/8th of Nation's Commercial Forest
Land is in the Lake States**



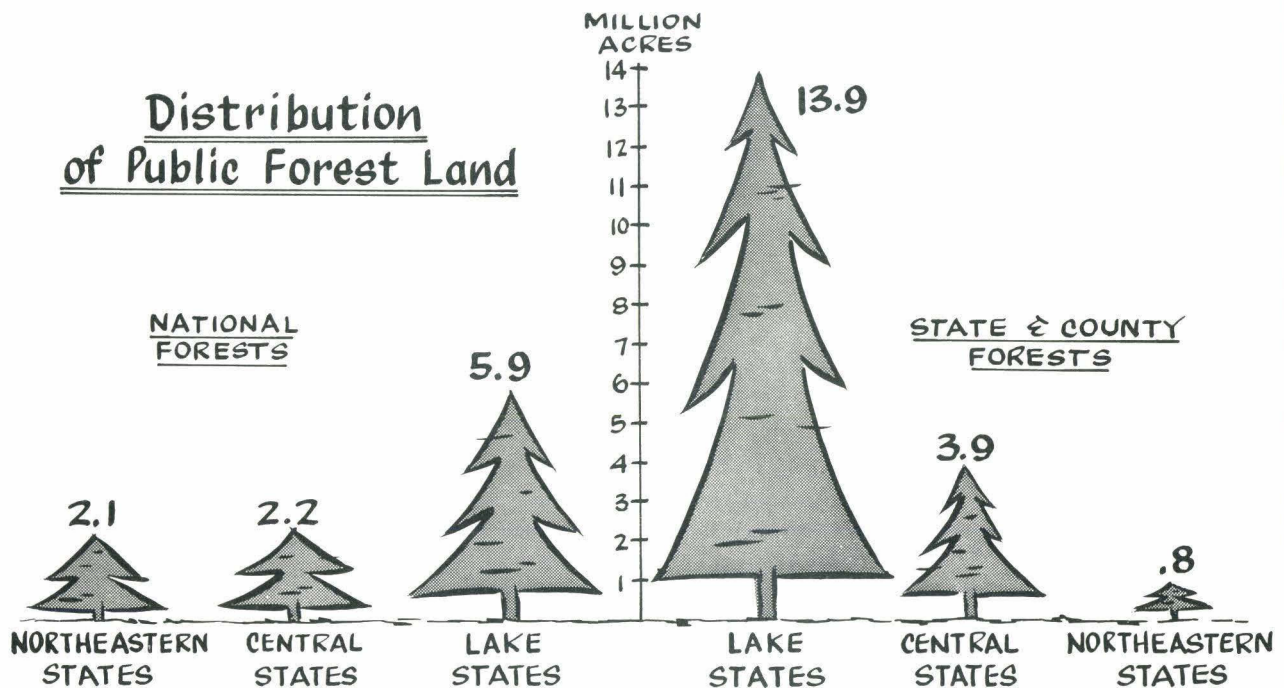
**Young Forests and Small Timber
Characterize Lake States**



40% of Forest Area is in Public Holdings



Distribution of Public Forest Land



Fragmentation of Forest Holdings..... (MICHIGAN, MONTMORENCY COUNTY)

In 1946 - ONE OWNER.....
THIS 7840-ACRE BLOCK OF FOREST
LAND WAS OWNED BY A SINGLE CORPORATION

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

T 30N - R 1E

By 1963 - 67 OWNERS..

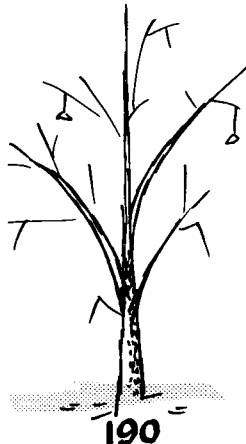
THIS SAME 7840
ACRES HAD BEEN
DIVIDED INTO 67
SEPARATE
OWNERSHIPS.....

AVERAGING 117
ACRES IN SIZE

TREE DISEASES.....

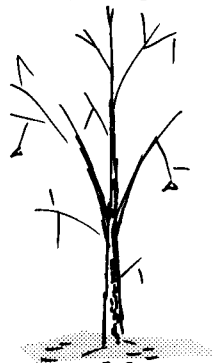
ANNUAL MORTALITY IS
LARGE IN LAKE STATES

11 WESTERN STATES



190

3 LAKE STATES



166

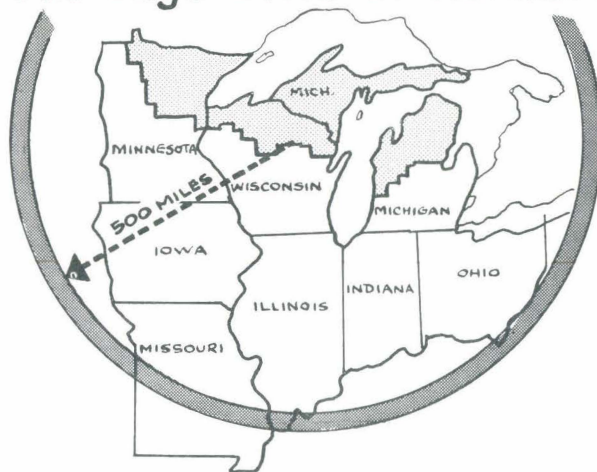
11 SOUTHERN STATES



73

— MILLION CUBIC FEET —

25 % of U.S. Population is within
One Day's Drive of Northern Lake States



Changes in Recreation Demand

LARGE INCREASES

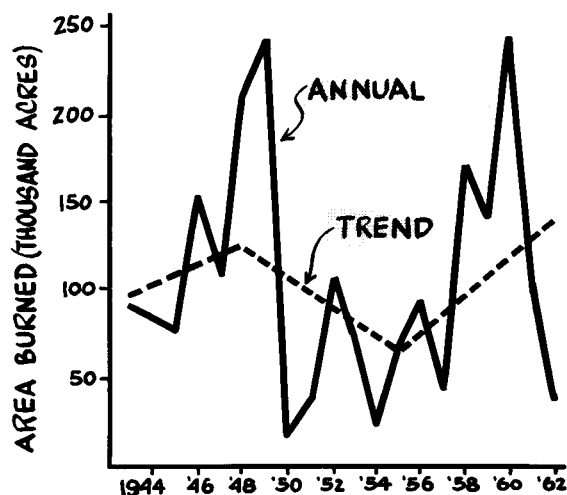
Wilderness Canoe Country (1946-'62)-up 680%
National Forest Camping (1946-'62)-up 350%
Winter Sports on
National Forests (1946-'62)-up 250%

SMALLER INCREASES

Number of resorts (1946-'62) up only 92%
Fishing licenses (1946-'56) up only 66%
Hunting licenses (1946-'56) up only 58%



Lake States Area Burned Trend Not Improving



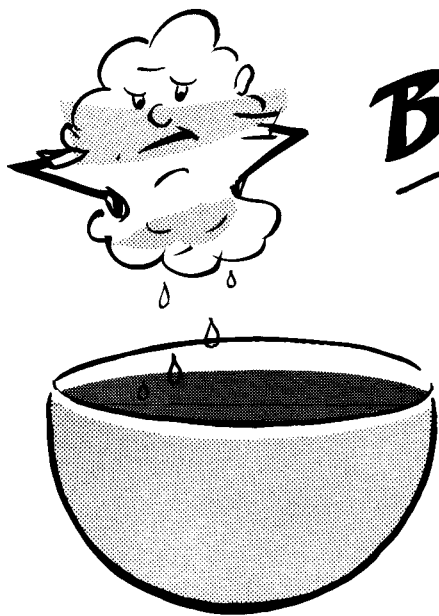
**MORE THAN 50% OF ALL FOREST FIRES
IN LAKE STATES ARE CAUSED BY DEBRIS
BURNERS AND SMOKERS!**

WATERSHED

WE HAVE SEEMINGLY VAST WATER RESOURCES IN LAKE STATES

- * 50,000 miles of Rivers & Streams
- * 25,000 Lakes
- * 10-million acres of Swamps & Bogs

MORE THAN 5% OF LAND AREA IS WATER SURFACE



BUT—

THIS IS AN
ILLUSION OF ABUNDANCE!

*MOST WATER IS COLLECTED IN
MORAINAL DAMS.....*

Annual Precipitation —
IS ACTUALLY LESS
THAN THE NATIONAL AVERAGE

Annual Runoff —
TOO, IS SOMEWHAT LESS
THAN THE NATIONAL AVERAGE

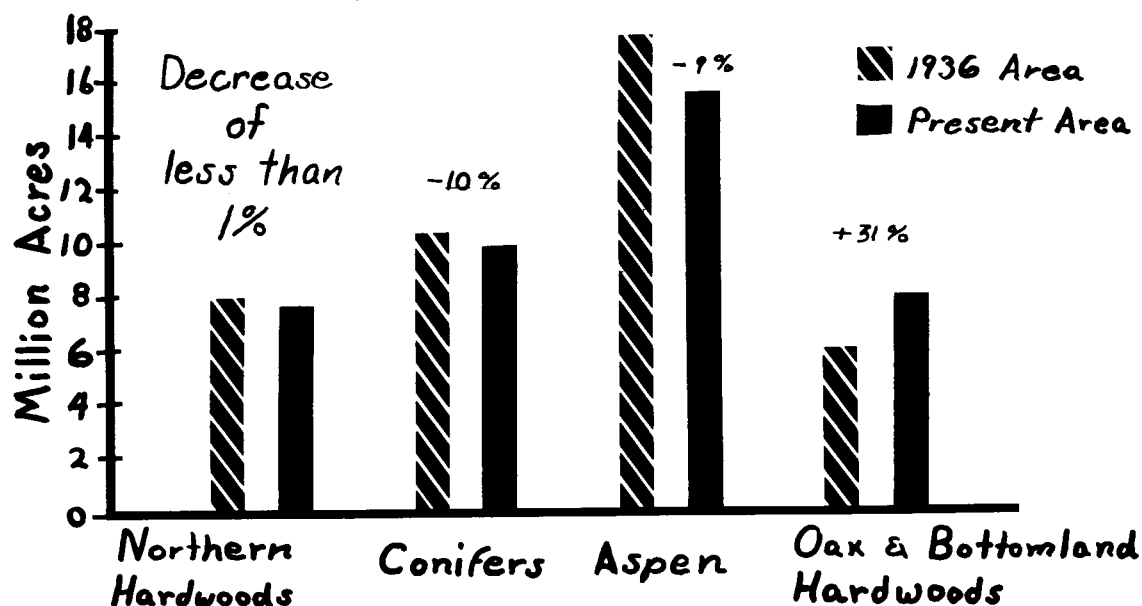
MEANWHILE—

COMPETITION FOR WATER IS INCREASING

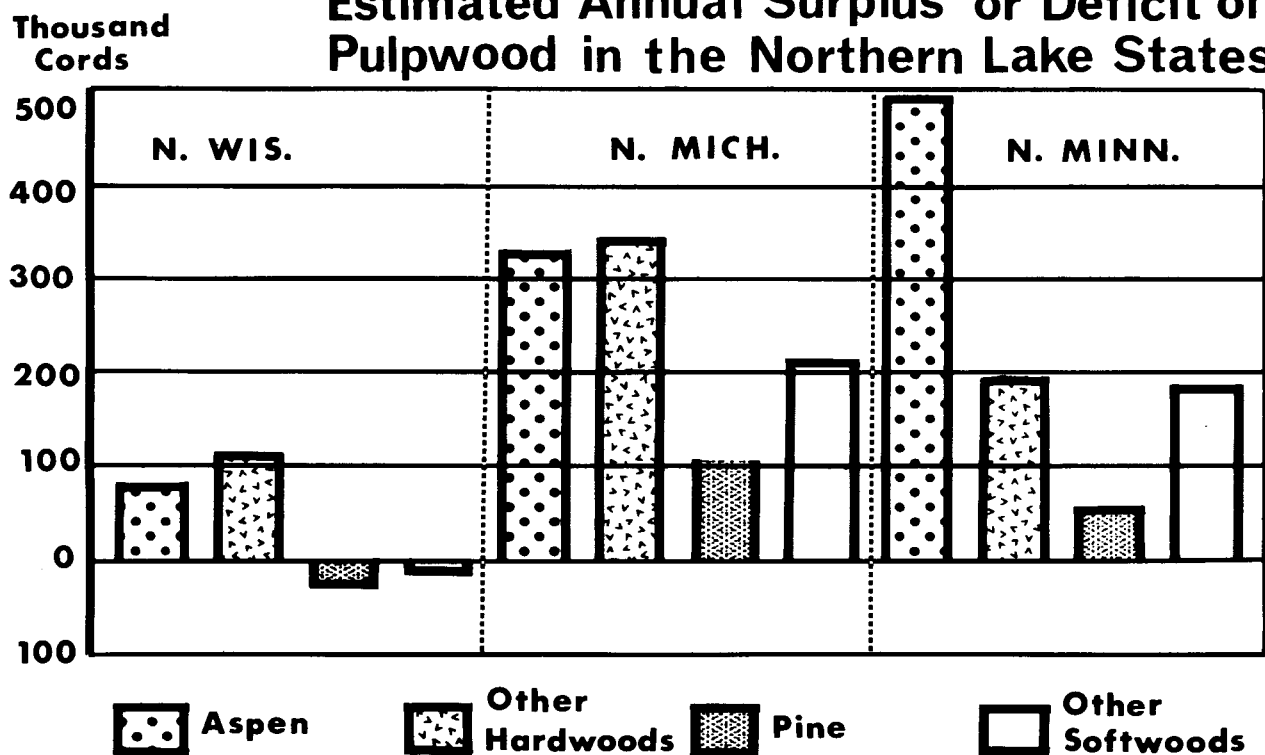
- * Between recreation + downstream users
- * Each type of user needs more water than before
- * Lake States water supplies have interstate & even international importance



Change in Lake States Forest Types, 1936 to Present



Estimated Annual Surplus or Deficit of Pulpwood in the Northern Lake States





U. S. FOREST SERVICE

The Northern Hardwood Forest

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE



Carl Arbogast, Jr., Project Leader,
Silviculture of Northern Hardwoods.
Located at Northern Hardwoods Laboratory,
Marquette, Mich.

The northern hardwood timber type is characteristically a climax forest. Although the mixture of tree species that grows in this forest varies from north to south and from east to west, the northern hardwoods are all tolerant of shade and can reproduce themselves on the forest floor or in small natural openings without the aid of major disturbance such as fire.

This forest can produce some of the most valuable timber in the Lake States region and is at the present time supporting a large segment of the lumber and veneer industry in the area. However, the most valuable and least valuable trees in the Lake States can often be found growing side by side in this timber type. With the excep-

tion of basswood, trees less than 12 inches in diameter are not merchantable for sawtimber, and trees under 16 inches but over 12 inches have low value. Rot, crookedness, and limbiness cause many of the trees above 16 inches to be unmerchantable, or nearly so. The value of large, straight, clear trees differs by species. At the present time, yellow birch commands the highest prices, followed by sugar maple and basswood. Other species are valued considerably lower.

The northern hardwood forest has high esthetic, wildlife, and recreational values. It can be expected that an increasing proportion of the land now devoted to timber production will be reserved for other purposes in the future, unless it can be demonstrated that forest management for commercial timber production does not deteriorate these values.

The general problem in northern hardwoods management is to devise silvicultural methods for reproducing and growing to maturity the kind and quality of trees that will provide industry with raw materials and fiber for the manufacture of saleable products for existing and future markets. Esthetic, wildlife, and recreational values should be protected and enhanced as the timber grows.

Figure 1.--Technician removes twigs from a 40-foot sugar maple to study epicormic shoot development.



SILVICULTURAL CONTROL OF QUALITY

The value of northern hardwoods is determined primarily by individual tree quality. This quality appears to be governed by both the environment in which the tree is grown and its inherent characteristics. Therefore the control of quality in these stands depends upon the forester's ability to recognize quality characteristics at an early age and to control environmental conditions, permitting trees with high potential to develop the quality desired.

Before time and energy can be expended in controlling the environment for quality development of an individual tree, it is essential that potential be recognized at an early age. At present, empirical and intuitive standards are used. But these are subject to doubt and discussion and can only be applied to trees of relatively advanced size (30 to 40 feet tall). Much site potential is wasted on the growth of undesirable individuals because of this inability to recognize elements of quality earlier in the life of a tree.

All tree species in northern hardwood stands develop dormant buds. Under certain environmental conditions these buds will develop into epicormic sprouts that will persist until they become large limbs (fig. 1). Thus young trees with high quality potential can deteriorate if proper environment is not maintained. The effects of environment on natural pruning, forking, and epicormic shoot development are not adequately understood.

COMPOSITION

As was mentioned earlier, an important element of economic quality is species. When individual tree quality is high, there are large differences in value by species (fig. 2). For example, a high-quality yellow birch log has just about double the value of a sugar maple log of the same quality and size. These differences become less marked as log quality becomes poorer.

In any event the silvicultural value of a mixed stand may outweigh the economic considerations. Northern hardwoods on most sites tend toward a sugar maple monotype. Monotypes are susceptible to catastrophic attacks by insects and disease. Also, a



Figure 2.--High-quality yellow birch and sugar maple, standing side by side, are valuable components of this northern hardwood stand.

single species may not reach best development without a mixture of other species in the stand.

In order to manipulate the composition of northern hardwood stands at will, we need to know more about the environmental requirements of all species in the complex--how does environment affect reproduction and early development, flowering and seeding characteristics, and symbiotic relationships between species (fig. 3).

STAND TENDING AND SILVICULTURAL SYSTEMS

The results of the more fundamental studies of quality and composition control will have to be applied to the management of the forest before they can affect the production of the land. The step between the recognition of fundamental relationships and the application of this knowledge to the management of the forest involves long-range and complex research. This work, however, needs to be carried on concurrently with the more basic investigations so that results of these projects can be made currently available to forest managers in the region.

A high proportion of the work at the Experimental Forests at Dukes, Mich., and Three Lakes, Wis., has always been devoted to this type of experimentation. Comprehensive studies of silvicultural systems, including shelterwood and variations of

Figure 3.--Research workers prepare an area for studying the effect of seedbeds, light, and moisture on yellow birch regeneration.





Figure 4.--Research Forester and technician mark
a stand for an experimental cut.

clear cuttings, are underway (fig. 4). Also, studies involving intermediate cuttings in immature stands have been established on both Experimental Forests. These involve aspects of thinnings, cleanings, and improvement cuts. With the planning and establishment of coppice studies, a broad base of empirical studies will have been established. The results of more fundamental studies can be superimposed upon these in the future.

The feasibility of various management systems applications differs with the policy of the owner and the size of the property involved. Methods that may be highly

desirable on medium or large ownerships may have little attraction for owners of smaller areas. Also, owners who are mainly interested in the production of timber may need a different system of management than those who are interested in maintaining and enhancing esthetic, recreational, wildlife, and other uses, as well as timber production. This phase of the research project is designed to be broad enough for analysis under many assumptions. It must include elements that will evaluate the impact on the forest of many different uses and combination of uses, as well as timber production.



U. S. FOREST SERVICE

Diseases of Northern Hardwoods

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Dr. John H. Ohman, Project Leader,
Diseases of Northern Hardwoods.
Project is located at the Northern
Hardwoods Laboratory, Marquette, Mich.

Northern hardwoods disease research is directed toward developing methods for reducing or eliminating the impact of diseases on the northern hardwood type in the Lake States. Before this can be accomplished, research must uncover the causes of the diseases, the life histories of pathogens involved, and the ecological factors affecting their spread and prevalence. When these have been determined, biologically sound control recommendations can be made.

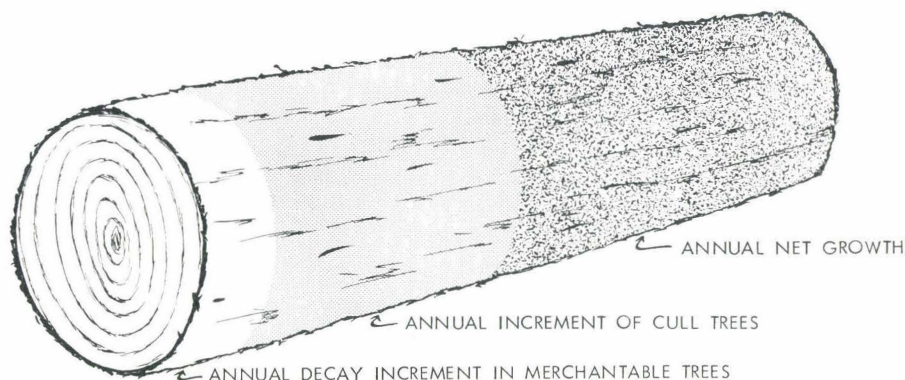
The great majority of known northern hardwoods diseases do not kill but rather deform, discolor, or decrease volume in living trees. The resulting low-quality trees will remain in the stand for many years, taking up growing space which should be producing more valuable trees.

DECAY

Decay is by far the most important disease problem. It is responsible for essentially all of the growth impact caused by disease in northern hardwoods (fig. 1). Decay reduces board-foot production in merchantable northern hardwoods by an estimated 20 percent. In addition, standing cull trees have an annual growth of 226 million board feet, which is a total loss. The annual losses from heart rot are estimated at 290 million board feet. Current annual net growth is probably slightly less than the annual decay increment.

One important consideration is the fact that nearly 80 percent of the growth impact from heart rot is in cull trees. Therefore, as the level of forest management rises and these standing culls are replaced by merchantable trees of higher quality, heart rot losses will decrease. However, the annual loss from heart rots would still be far greater than that of any

Figure 1.--This illustration shows the growth impact of decay in northern hardwoods.



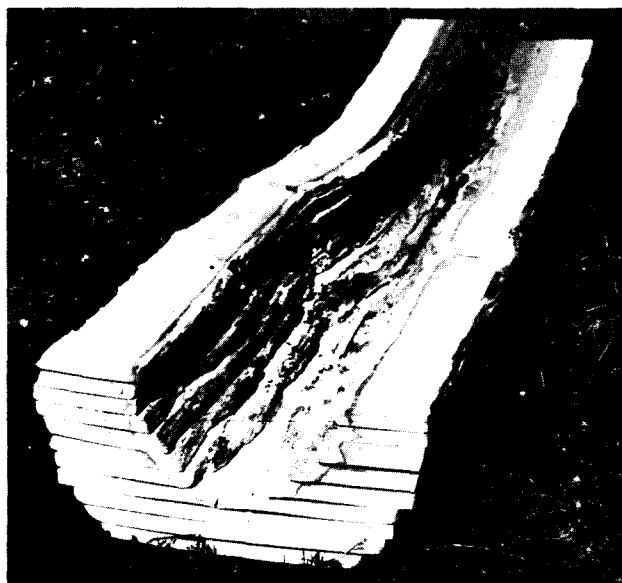


Figure 2.--Decay has made this sugar maple butt log valueless, since the costs of manufacture exceed the value of the few good boards that it contains.

other northern hardwoods disease even if cull trees could be completely eliminated.

Though the numerous combinations of tree and decay fungus species have widely varied characteristics, these generalizations can be made concerning the northern hardwoods decay problem: (1) High unit values are based on high quality saw logs. Decay greatly reduces the proportion of such logs (fig. 2). (2) All of the tree species are highly susceptible to decay. (3) The currently recommended selection system of management, with its frequent partial cuts, provides opportunities for injury and disturbance of the residual stand. This intensifies heart rot problems. However, it also provides opportunities to remove defective and high risk trees. It is likely that the advantages of the latter outweigh the disadvantages of injury and disturbance.

Research should include the following: (1) Identify the principal fungi involved, then determine their infection requirements and rate of advance after establishment. (2) Determine the influence of site and stand characteristics on prevalence and development of heart rot. (3) Develop a risk classification system for predicting susceptibility to decay in individual trees. This will serve as a guide in crop

tree selection. (4) Develop improved methods for estimating internal defect in individual trees on the basis of external symptoms.

Because of the large number of host-pathogen combinations in the problem, work in the four preceding categories is necessarily limited to a few of the more important combinations.

STAIN

Stains reduce tree quality. Data on the amount of loss are not available, but since stains of various types are common in sugar maple--the most important species in the type--the loss is large. Forest managers and manufacturers of northern hardwood lumber have expressed their concern about the problem.

Present knowledge of stains in sugar maple is extremely limited, with causal agents and control unknown. Dark heart, or black heart, is most common and widespread (fig. 3). Affected trees have a central cylinder of very dark brown wood. The proportion of the stem involved and the color of the stain vary considerably. The greatest loss in grade occurs when the discoloration is very dark and extends well beyond the normal heart zone in the log. Sugar maple is also subject to a discoloration called mineral stain or mineral streak. It may well be that this is actually another manifestation of dark heart. Yellow birch is also subject to serious staining.

Logging injuries are particularly good entrance points for such stains. They are also found in trees of declining vigor. In this case, also, causal agents are not known but micro-organisms are almost certainly responsible in some instances. Research needs in the stain problem are very similar to those for decay. However, greater emphasis must be placed on determining causal agents.

WILTS AND DIEBACKS

So far as is known, diseases of this type cause relatively minor damage on northern hardwoods tree species in the Lake States. However, some of them have potential for far greater damage than they cause at present. For this reason it is necessary that these receive immediate attention in the research program.

Maple blight.--This disorder was the cause of widespread alarm when it was first noted in 1957 and it caused rapid mortality of trees in all size classes. In some cases, losses were nearly 100 percent. Recently, research conducted by the Station and various cooperators, financed in part by the hardwood lumber industry, has shown the cause to be insect defoliation coupled with frost damage to regrowth. Thus, this is now considered to be an entomological rather than a pathological problem.

Sapstreak.--This disease was originally reported and described in North Carolina, where it caused considerable damage in a relatively small area. It was first discovered in the Lake States in 1960 on a single tree in the Upper Peninsula Experimental Forest. Since that time several more cases have been found in the Upper Peninsula of Michigan and a survey is being made to determine its prevalence. Up to 10 percent of the sugar maple cut in some stands during the past winter on the Upper Peninsula Experimental Forest had sapstreak. Infected trees die eventually, but even when salvaged before death, they are of little value since lumber sawn from infected logs is badly degraded by the stain.

The potential for sapstreak damage in the Lake States is not known, but since the fungus is closely related to those causing oak wilt and Dutch elm disease, the possibility for great damage exists.

Dieback.--This condition is widespread on a number of northern hardwoods species. Its cause is unknown. The crowns of affected trees usually die from the top down, until up to 50 percent or more of the crown is destroyed (fig. 4). The condition then becomes stabilized and regrowth begins. After several years the crown may be replaced. Affected trees rarely die. It is most severe in larger size classes and in heavily cut stands.

A considerable amount of research is presently being concentrated on sugar maple to determine the cause of dieback and evaluate the damage.

STEM CANKERS

With the exception of hemlock, all northern hardwood species are susceptible to



Figure 3.--The stained interior of this sugar maple log is caused by dark heart. The affected area will produce only the lowest value lumber.

various stem cankers. The incidence of the different cankers varies greatly from stand to stand, but they are readily detected and selective cutting affords ample opportunity for removal of infected trees. For these reasons, the problem is not as serious as it might be.

Cankers decrease tree quality through distortion and discoloration of the bole. They decrease stand volumes, serving as entry points for decay fungi, and mechanically weaken the stem so that wind breakage occurs. They sometimes kill directly by girdling the stem, especially on smaller trees.

Research is needed (1) to determine modes of infection, (2) to discover factors influencing spread and prevalence, and (3) to develop methods of detecting the presence of cankers in the incipient stage to facilitate early removal.



ROOT ROTS

The only known root rot of consequence in the type is caused by Armillaria mellea. At present, pathological opinion is divided as to whether the fungus is a primary pathogen capable of invading a healthy host or a secondary one that will invade only hosts already weakened by some other factor. Even if only secondary, however, it is probably killing trees that might have recovered in its absence.

Figure 4.--All northern hardwoods species are susceptible to dieback. The cause is unknown as is the amount of damage attributable to it. Affected trees rarely die.

All northern hardwoods species are susceptible, to some extent. A small-scale study of infection requirements for the fungus on sugar maple is being made, but more research is needed on factors influencing its spread and prevalence.

SEEDLING DISEASES

The only disease of this type known is a Diaporthe canker of yellow birch seedlings, but others are probably present. A limited amount of research is being done on the birch canker and a study of seedling mortality has been started to better define the problem.

LEAF SPOT

All northern hardwoods species are susceptible to various leaf spots. Their economic impact on the host is very small, however. They become a problem only in shade trees where the unsightliness of the affected foliage is objectionable. No research is needed at present.



U. S. FOREST SERVICE

Timber Quality Research in the Lake States

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Richard M. Marden, Project Leader,
Timber Characterization and Process-
ing. Project located at Wausau, Wis.

In 1954 forest products utilization research was started at the Lake States Forest Experiment Station, and in 1961 a forest engineering project was set up at Houghton, Mich. The primary objective of utilization and engineering research is to develop economic methods of using the large surplus of small and low-quality trees in Lake States forests. Removal of these trees will provide adequate growing space for the needed production of high-quality wood in desired species and size classes. Among the subjects needing study are tree-quality criteria, effects of environment and treatment upon tree quality, wood-processing methods, wood in use, and engineering improvements to reduce wood-handling costs.

Tree-quality investigations are aimed at providing information for timber appraisal work to assure equitable sales transactions and to determine the effects of stand treatments upon the quality of growing stock left after cutting. We need to know when a tree will provide its highest market value and best use and also what a tree's potential value will be if it is left as growing stock. The ability to accurately ascertain and control factors of timber quality may ultimately be the key to profit in timber growing, processing, and marketing.

Lack of such basic information has been the greatest deterrent to the development of satisfactory tree grades.

The tree-quality study is intended to bridge this gap.

A current major utilization project is the development of a method for estimating the value of standing sugar maple trees for specified end products. Objectives are to:

1. Calculate equations for estimating values of Lake States sugar maple trees by relating tree stem characteristics to the yields of certain products.
2. Compile a photographic guide for sugar maple to show the relationships between exterior defect indicators and the underlying wood. The guide will be used as a working tool in the application of the tree-grading equations developed in the first objective (fig. 1).

The five-step program to accomplish these objectives is summarized below:

1. Develop the necessary techniques for collecting and analyzing basic timber-quality data.
2. Collect and analyze an adequate sample of sugar maple so that estimating equations for predicting tree yields can be calculated.
3. From the data obtained in Step 2, develop a reliable tree-grading system.
4. Field test the system developed in Step 3.
5. Assist forest managers and timber users in applying the grading system.

The first step (techniques) has been completed, and Step 2 (collecting and analyzing data) is in progress. Both our objectives--calculating useful estimating equations and developing a photographic guide--can be achieved with the same fieldwork.

Many stem characteristics are important for predicting the amounts of wood meeting given product specifications. Some are visible defect indicators on the tree's exterior, some have to do with tree form, and others are on the interior with no obvious outer signs of defect. Among the common visible indicators are overgrown knots, sound and unsound knots, seams, bumps, raised surfaces, and bark distortions. Tree form characteristics are stem taper, crook and sweep, diameter at breast height, and merchantable stem length. Interior characteristics are tree age, growth rate, and hidden defects. If interior characteristics are correlated with wood quality, indirect measurements of these factors can be used. The exterior defect indicators have the greatest effect on wood quality, hidden defects can be nearly as important, and form probably has the least effect but cannot be ignored.

For the study, approximately 180 trees will be selected to sample sugar maple within its normal range in the Lake States. The 180 trees will come from four 45-tree samples: two from the Upper Peninsula of Michigan and two from northern Wisconsin. The fieldwork for the two Michigan samples has been completed, and the analysis is nearly finished. Each sample is being analyzed separately; and if there are no differences between stem characteristics and wood quality, data from the total sample of 180 trees will be pooled and analyzed as a unit.

Sample trees between 11 and 26 inches d.b.h. and covering the existing quality range were selected from old-growth northern hardwood stands. Standing tree characteristics, such as d.b.h., crown class, and lean, were measured. Immediately after felling, crook and sweep were also measured. An orientation line was marked the full length of the stem, each tree bucked into 16-foot logs, marked with log position number, and transported to the Ford Forestry Center, Michigan College of Science and Technology, at Albion, Mich., for later examination and dissection.



Figure 1.--Exterior defect indicators are located, their key numbers are placed on the diagram board, and then the entire setup is photographed.

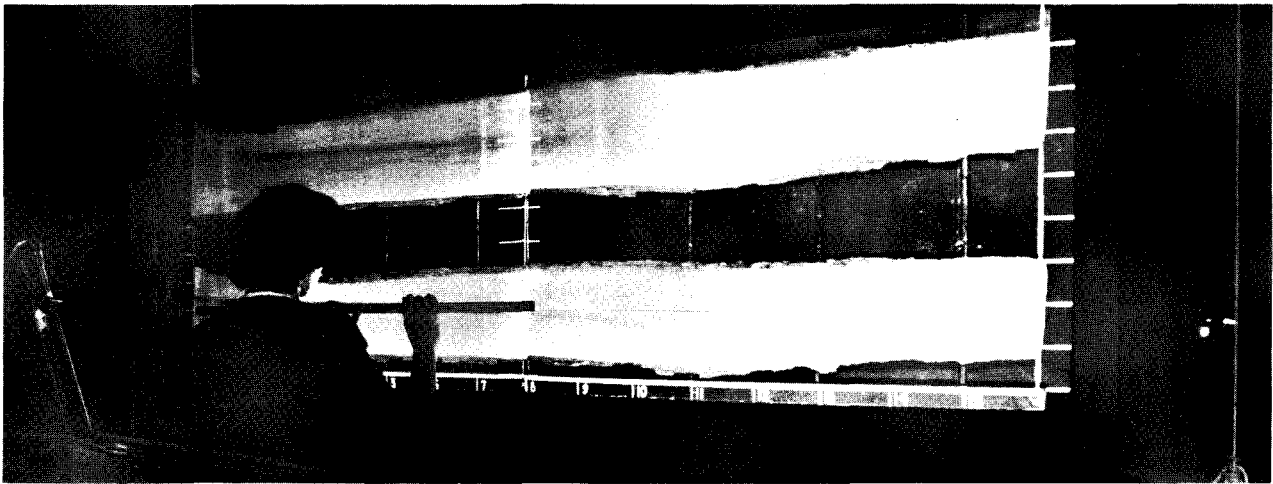


Figure 2.--Clear cuttings between defects are measured on the projected images of the flitches and the volume in each size class totaled for the tree.

To facilitate handling, logs were cut into 8-foot lengths. Two-inch-thick disks cut from the butt of each log were photographed to provide log end descriptions, and the disks were sent to the Forest Products Laboratory at Madison, Wis., where age, growth rate, and specific gravity determinations were made.

The logs' exteriors were photographed with the help of the special diagram board and lighting setup shown in figure 1. All exterior defect indicators were located, tabulated, and photographed in color.

Each log was sawed "through and through" into 1-inch-thick flitches which were identified for later reconstruction of logs and trees during interior examination.

Interior defects were identified and the flitches photographed in color. The flitch transparencies provide a permanent record which allows yields to be measured for several products. Yields of various classes of wood from a tree are expressed as percentages of the tree's gross volume. In this study, tree quality is based on relative proportions of volume contained in various analytical grades of clear cuttings (fig. 2). As a final step in the

analysis, the analytical grades will be correlated with standard lumber grades.

The relationships between various tree stem characteristics and the proportions of the tree volume in each cutting class are being determined by using multiple regression analyses methods and high-speed computers. An equation is calculated for each of the product classes.

In actual practice, the forester will observe the stem characteristics in the grading section of the tree, record them on field punchcards, and send the cards to a data processing center (fig. 3). The computer will apply prediction equations developed in the study, using current product prices, and express answers in dollar values.

When the system has been perfected for sugar maple, the technique will be used for other important northern hardwoods, such as yellow birch and American basswood.

Valuable assistance on the quality study has been received from the following cooperators: Michigan College of Science and Technology, Kimberly-Clark Corporation, U.S. Forest Products

Laboratory, and National Forest Administration.

Other aspects of the timber-quality problem also are being investigated. In 1956 a study was started to determine optimum growing stock levels in northern hardwood pole stands to produce a balanced, mature stand with continuous high-quality and volume growth. Several bolter saw studies, in cooperation with the University of Michigan, have been undertaken to improve the feasibility of economically sawing short bolts and top branch wood. The studies show that utilization and dollar return can be increased by using a short-log bolter in conjunction with the main sawmill.

The Forest Products and Engineering Research Division is conducting other studies intended to improve the utilization of wood. For example, in cooperation with the University of Minnesota, we are working on the design of farm buildings, new fencing methods, and preservative treatments. We are also cooperating with the Michigan College of Science and Technology at Houghton, Mich., on studies aimed at reducing the costs of harvesting and transporting wood.

Coordinated efforts of researchers in the various phases of forestry have resulted in answers to many problems. Similarly, the fundamental research by other workers on the reactions of trees to various environmental conditions will be helpful in the solution of many utilization problems.

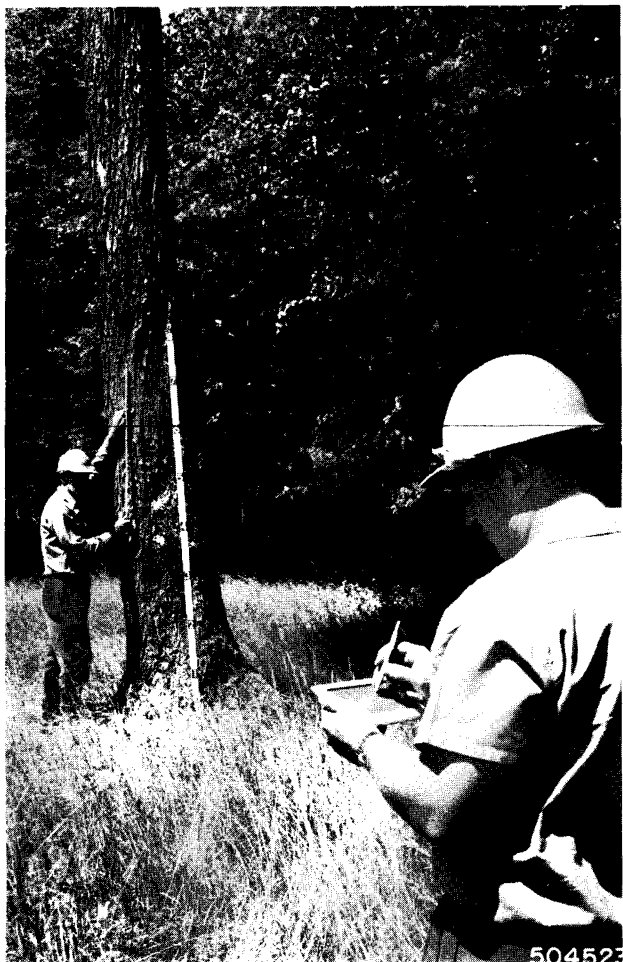


Figure 3.--Tree characteristics are measured in the grading section of the stem and recorded on field punchcards for later analysis.



U. S. FOREST SERVICE

The Hydrology of Northern Bogs and Swamps

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Roger R. Bay, Project Leader,
Bog and Swamp Hydrology.
Located at Northern Conifer Laboratory,
Grand Rapids, Minn.

Over 15 million acres in the Lake States are covered with organic soils (fig. 1). Most of this area is located in northern parts of Minnesota, Wisconsin, and Michigan. These are strategic watershed lands because the streams which arise from them contribute water to the Mississippi, Great Lakes, and Hudson Bay drainage systems. Most of the wetlands and their associated uplands are forested, and forestry will probably continue to be their dominant use.

Northern bogs vary in size, depth, geologic origin, physical makeup, and hydrologic behavior. Little is known about their hydrology, yet they have received considerable attention from land managers. In the past, bogs have been drained, burned, and dammed. They've been called everything--from sponges to reservoirs or regulators of water supply. Now, foresters are again considering bog drainage or water level control for site amelioration, and the public and industry are speculating

about bogs as important water supply areas. Before any manipulation of wetlands is attempted by drainage, cutting methods, conversion, or water impoundments, it is necessary to study the entire hydrologic role of bogs--their regulation of streamflow, effect on water quality, and value to ground water recharge.

To meet this need for knowledge, the Lake States Forest Experiment Station initiated the bog hydrology project. Its objectives are to determine: (1) Basic hydrologic properties of northern bog lands, including interception, water storage characteristics, streamflow characteristics, and contributions to ground water recharge, and (2) effects of land management practices on water yields from northern wetlands and their surrounding upland areas. Researchers are attacking these problems on two fronts which are described in later paragraphs--one is the study of calibrated bog watersheds and the other is basic studies of peat soils.

CALIBRATED BOG WATERSHEDS

The calibrated bog watershed part of the research program is primarily a field operation. Five small bog watersheds have

Figure 1.--Over 15 million acres of wetlands dot the northern Lake States. How important are they? Should they be ditched or flooded, forested or treeless? The Lake States Station established its Bog and Swamp Hydrology Project to answer these and other equally important questions.



been instrumented to give a complete accounting of their inflow and outflow of water. A typical instrumentation scheme includes a weather station, a precipitation gage network, recording and non-recording wells in the bog, deep ground water wells outside the bog, and stream-flow measuring gages such as flumes and weirs (figs. 2, 3, 4). This instrumentation enables researchers to determine how much water falls on the bogs, how much runs off, how much is stored, and how much is lost through evapotranspiration.

After a suitable period of calibration to determine the normal behavior of water table fluctuations and streamflow, some of the watersheds will be subjected to various forestry practices and water level control procedures, both on the bogs and the uplands. At least one will be left in a natural condition for comparison with the treated watersheds to determine treatment effects.

Some of these bog watersheds have been instrumented for 2 years now, and important information has already been accumulated on annual water table fluctuations, rainfall, water table relationships, water yields from natural bog areas, and the geology of small bog areas. These early records indicate that bogs do not supply unlimited storage. Each has its fixed capacity. Also, not all bogs are good regulators of streamflow over the entire year. In fact, early streamflow records indicated that 65 to 80 percent of the annual runoff from the experimental bogs occurred during 2 months in spring. Thus, water storage and regulation abilities of bogs are dependent upon many physical properties of both the bogs and their surrounding uplands--size, topography, source of

water, and character of the peat soil. These are being studied.

STUDIES IN PEAT SOILS

Research on the physical and hydrologic properties of organic soils under natural field conditions has been neglected in the past. Yet, to fully understand bogs and peatlands as watersheds, it is necessary to know about these important properties. The soil in a bog watershed is the reservoir where water is stored. The different physical and hydrologic characteristics of this peat determine how much water is stored and how fast water moves vertically and horizontally through it. Thus, storage capacity of the peat will influence water table fluctuations and the amount of water held after drainage. And the rate of water movement, together with storage capacity, will determine the amount and timing of outflow from bog areas.

Both laboratory and field studies have been concerned with water storage and rates of water movement through various types of peat. In the laboratory, specialized equipment was developed and used to determine the amount of water held in peat at various tensions. In the field, piezometers were used to measure water movement rates, or hydraulic conductivity. These studies have provided basic information that enables scientists to understand the hydrology of peats and to plan specialized studies on evapotranspiration and drainage.

Recently completed studies have shown that water storage characteristics of peats vary considerably. All peats, when saturated, contain a great deal of water; the real difference is the manner in which it



Figure 2.--Weather stations have been installed on the experimental bog watersheds to record climatic conditions that can later be correlated with the data gathered from other instruments in the area.

is released. Sphagnum moss peat has many large pores that are easily drained at low tensions, while decomposed peats have many small pores that contain a great deal of water, even at high tensions (fig. 5).

Striking differences can also be seen in the rate of water movement within different peat types. While rates as high as 118 feet per day were found in surface horizons of undecomposed moss peat, movement through deeper decomposed peats was as low as 0.016 foot per day.

These results indicate that in some bogs surface horizons are most important to watershed management because of high specific yield and faster water movement rates--both desirable aquifer characteristics. The deeper, more dense, horizons provide little storage capacity, and water movement is very slow (table 1). Thus, peat soils vary in aquifer characteristics much like mineral soils.

Further studies of physical and hydrologic properties of these and other peat types are continuing. With these data, foresters and hydrologists will be better able to understand and predict the watershed features of bog areas.

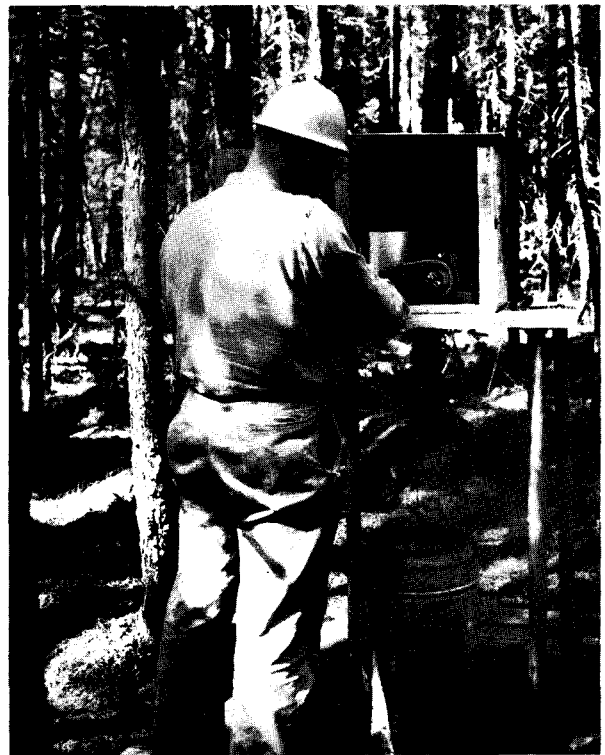


Figure 3.--Recording wells are essential instruments in the experimental bog watersheds on the Marcell Experimental Forest. They keep accurate records of bog water table fluctuations throughout the year.

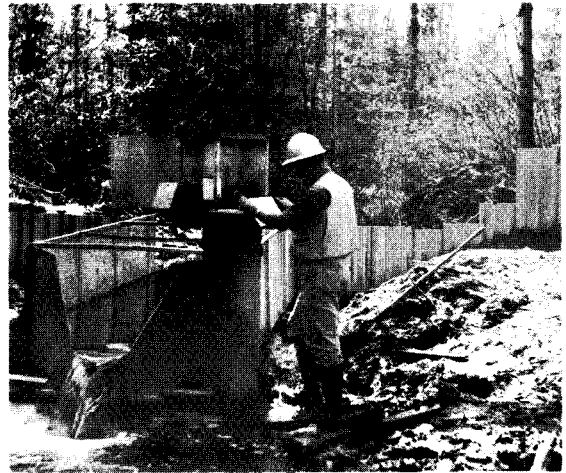
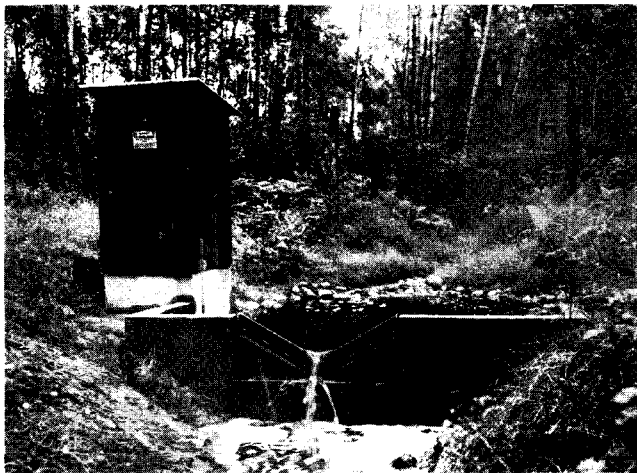


Figure 4.--Weirs and flumes have been installed on the outlets of bog watersheds to measure streamflow. Pictured are two types presently in use--a V-notch weir (left) and an H-type flume (right).

Table 1.--Aquifer characteristics of several peats
and mineral soils

Soil type	Porosity	Specific yield	Water move- ment rate ^{1/}	Aquifer class ^{2/}
	Percent	Gal./cu. ft.		
Moss peat (undecomposed)	95-99	6.43	Rapid	Good
Decomposed peat	81-85	.75	Very slow	Poor
Clean gravel ^{2/}	30-40	1.87	Very rapid	Good
Glacial till ^{2/}	40-50	.37	Very slow	Poor

^{1/} Water movement rates for specific hydraulic conductivity values given by: Marshall, T. J. Relations between water and soil. Tech. Comm. No. 50, Commonwealth Bureau of Soils. 91 pp., illus. 1959.

^{2/} Aquifer classes and mineral soil values from: Todd, D. K. Ground water hydrology. 336 pp., illus. John Wiley & Sons, Inc., New York, 1959.

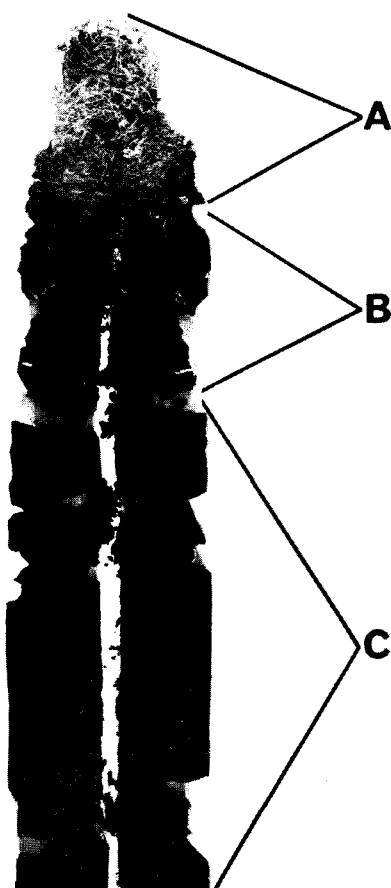


Figure 5.--This profile is the top meter of a northern peat bog. The three horizons are: A--undecomposed sphagnum, B--partially decomposed peat with wood inclusions, and C--compacted peat in varying stages of decomposition. Most water movement takes place in A and B. Very little movement, either vertically or horizontally, takes place in horizon C.



U. S. FOREST SERVICE

The Regional Variations of the Northern Conifer Peatland Types

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

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Silviculture of Northern Conifers.
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THE PROBLEM

Natural forest communities in Lake States peatlands vary widely in floristic composition and productivity. This is true of both the overstory trees and the lesser vegetation. For example, in Upper Michigan and Wisconsin are many productive mixed conifer swamps where northern white-cedar, balsam fir, black spruce, tamarack, red maple, and other trees grow in profusion. In contrast, in northern Minnesota there are vast areas of pure black spruce forest, and equally pure tamarack forest. Some of these pure spruce or tamarack forests yield good crops of pulpwood or other products. But intermingled with these better peatlands are large tracts of "muskeg" that at best will grow only small Christmas trees unless costly drainage and fertilization work is done. Similar muskegs occur in Michigan and Wisconsin, although less commonly. Still another terrain type occurs in Minnesota's "Big Bog" country, and near Seney on Michigan's Upper Peninsula. This is the naturally treeless grass- and sedge-covered bog (or "fen"), many of which are examples of the botanically interesting "string bogs."

Across the region there are distinct changes in the proportions of these peatland types. Such changes probably can be related to physiographic provinces and climatic gradients. We know, for example, that peatlands occupying the beds of extinct glacial lakes (such as Lake Agassiz in northwestern Minnesota or Lake Wisconsin in central Wisconsin) tend to differ from those on the Laurentian Shield in Minnesota, and from those on the glacial moraines and outwash plains. But many individual peatlands also seem to be a complex of several dis-

tinctly different swamp, bog, or fen types.

In the past, these variations have been explained largely in terms of stages of development in the classical filled-lake successional series. This series begins with an open-water stage; progresses through stages of aquatic plants, floating sedge mats, bog shrubs, and bog forests (of tamarack and spruce); and finally culminates with a mixed upland forest. The earlier stages can actually be seen surrounding many remnant bog ponds in the morainic areas and outwash plains. But, as we shall note later, the filled-lake succession fails to provide a theoretical framework for understanding the modern landscape in a large proportion of the region's forested peatlands.

To practicing foresters dealing with these peatlands, the need for additional knowledge of peatland types is clear. Two kinds of needs are often expressed: One is for a better means of recognizing and mapping productivity differences, especially where the virgin forest has been cut. This is important in planning allowable cuts, in deciding where certain management expenses are justified, and (potentially) in recognizing areas that may warrant expenditures for drainage or fertilization. The second need is for on-the-ground delineation of areas that will respond uniformly to silviculture measures. This is paramount to the solution of regeneration problems.

The growing area of lowland brush in the Lake States (4,885,000 acres as of the last survey) attests our failures in reproducing many swamp stands. This large nonstocked area is, of course, due partially to unrestricted cutting and burning in the early days, but throughout the region there still are problems with brush invasion and undesirable changes in stand composition after logging. Some black

spruce sites in northern Minnesota are relatively stable and seldom fail completely after cutting. But other spruce sites in Minnesota, Michigan, and Wisconsin are commonly taken over by shrubs and hardwoods. The mixed coniferous swamp types are unpredictable. Basic environmental factors and plant community variations seem to be responsible for these differences, but a basis for mapping out areas that will respond similarly has been lacking. Knowledge of this kind is essential to progress in the planting, direct seeding, or natural regeneration on peatlands.

Some way of describing environmental units on peatlands is also essential to progress in silvicultural research. We must be able to tell practitioners where our results will or will not apply but as yet there is little basis for decisions.

All of these problems demand, first, a better fundamental understanding of the peatland environment; second, a classification of peatland types useful in silviculture, and finally, mapping procedures so that areas with different management significance can be delineated on maps, at scales appropriate for field use.

A NEW APPROACH

A regionwide study of variation in peatland types is now underway, centered at the Station's Grand Rapids, Minn., laboratory. This systematic delineation of peatland types began in 1962 and will run for several years. It was preceded by a related study of growing conditions for black spruce in Minnesota. The approach is through basic peatlands ecology. We are attempting to learn how these varied peatland types developed, and what factors account for their modern vegetation patterns. The viewpoint is holistic and integrative--that is, we are studying entire peatlands, their vegetation, and their environmental setting as units. We have departed from traditional Lake States bog ecology by relying heavily on new lines of evidence instead of primarily on vegetation analysis, which was the mainstay of earlier work.

The method involves detailed ecological analyses of key areas, selected to cover the full range of peatland types. Officially designated Natural Areas are being

used where possible. The geologic and climatic setting of each area will also be analyzed and related to other factors. New approaches and techniques include:

(1) Topographic surveys of the peat surface and substratum. These will relate variations in peatland topography to directions and relative rates of water movement, and correlate both with natural vegetation types.

(2) Studies of the topographic alignment of vegetation types by airphoto and aerial reconnaissance.

(3) Determination of the stratigraphy of the peat deposit by peat borings to the mineral substratum at selected sites. These borings yield solid historical evidence of actual peatland development.

(4) Chemical analyses of bog waters to determine how water chemistry is related to floristic variation.

(5) Carbon-14 dates of significant peat horizons to establish an absolute geological time scale for key events in peatland history.

(6) Cooperation with the University of Minnesota geochronology and pollen analysis laboratory and with other interested geologists and botanists to relate peatland history to postglacial climatic oscillations.

In addition, the natural vegetation of each area will be documented to the extent necessary to establish correlations with other factors. This will usually include floral lists at key sites, ages and heights of dominant trees, and photo-interpretation of forest types.

SOME RECENT FINDINGS

Some of the findings presented here were obtained from the previous studies of black spruce growing conditions; additional findings already available from the 1962 and 1963 work are also given.

We now know that many of the region's northern conifer peatlands possess distinct surface slopes. Usually the fall is between 2 and 20 feet per mile. Many peatlands do not occupy fully enclosed basins, but instead lie on gently sloping

clay plains, in broad valleys, or on similar land-forms that provide impeded drainage but still allow continuous water movement across the area (fig. 1). Such



Figure 1.--Relief model of Lindford Peatland, Koochiching Co., Minn. Dark areas in center of model are productive black spruce peatland forest. Light areas within peatland are poor muskeg; outside they are mineral soils. Horizontal scale 2 by 3 miles. Vertical relief in 2-ft. contour steps (scale exaggerated).

peatlands could not have formed entirely by the classical lake-filling process. Instead they seem to be built-up peatlands, formed by a "swamping" process: As peat accumulates, the level of the peat surface and the water table rise. Progression toward stable upland forest communities is doubtful under such circumstances. In fact, there is widespread evidence of gradual long-term deterioration of growing conditions for trees in these peatlands. In some cases, for example, there are good basal forest peats lying beneath 7 feet or more of poorly decomposed *Sphagnum* moss. Only the poorest "muskeg" communities now occupy these areas. This is a common situation in the glacial Lake Agassiz region of northwestern Minnesota.

On the other hand, there are thousands of small filled-lake bogs in the morainic areas and on outwash plains. In many of these bogs little remnant ponds still exist where the lake-filling process can be witnessed today. Actually there seems to be a continuum from the filled-lake bogs to the built-up peatlands. Many in-

dividual peatlands were probably formed by a combination of both processes. An example of this type has been studied near Big Falls, Minn. (fig. 2).

There are indications that the vegetation types of many peatlands can be better understood by relating them to water movement patterns and to ground water chemistry than by reference to a hypothetical stage of "succession." The key may be the degree of isolation of given areas from mineral-influenced ground water. Isolation is a function of kinds of peats, thickness of the peat layer, distance from upstream mineral soils, steepness of peat slopes, and configuration of the peatland surface. Maximum isolation seems to be achieved with thick accumulations of *Sphagnum* moss on gentle slopes, far from mineral soils, and in locally convex areas.

The course of mineral-influenced waters through bogs is often marked by "water track" vegetation types. Such types show perfect topographic alignment, and are easily recognized on aerial photographs by a trained photo-interpreter.

Progress is also being made in identifying and naming peatland types. We have recognized for the first time that several types of "patterned bogs" occur in the Lake States. These include the "string bogs" and "fields" of topographically oriented forest islands (on peat) growing in the midst of large expanses of treeless bog. The string bogs exhibit a pattern of parallel micro-ridges and hollows, with the peat ridges oriented across the slope. These ridges support string-like communities of dwarf birch. The topographically oriented forest islands are teardrop-shaped, with their "heads" pointed upslope.

Studies of the region's least productive forested or even treeless peatlands are proving as useful as the investigations of productive areas. We are seeking principles in this study, and some of the poorest areas reveal most clearly the factors that control productivity and floristic composition. Much remains to be done before a comprehensive regional treatment of peatland types can be proposed, but the results so far are encouraging.

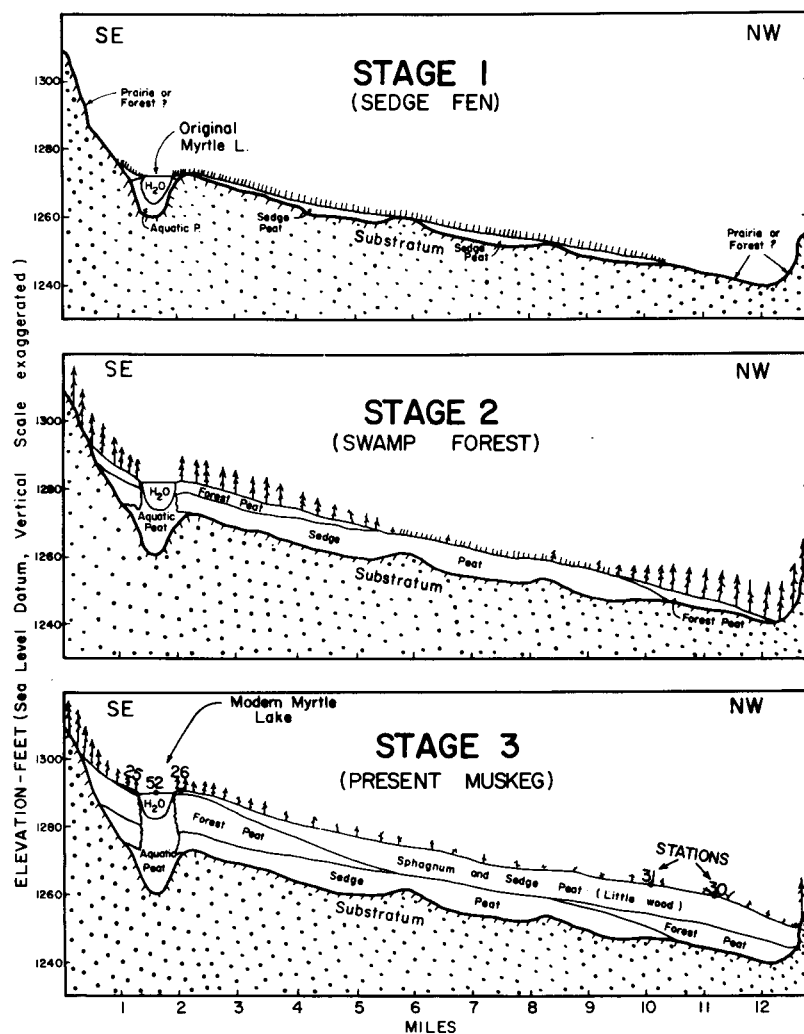


Figure 2.--Idealized sketch of the apparent history of the Myrtle Lake Peatland, Koochiching Co., Minn. This peatland was formed by a combination of lake-filling and bog expansion or "swamping."



U. S. FOREST SERVICE

Forest Wildlife Habitat Project

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Forest W. Stearns, Project Leader,
Wildlife Habitat Research. Located at
Station Headquarters, St. Paul, Minn.

INTRODUCTION AND BACKGROUND

Wildlife is an important resource of Lake States forests, and its abundance is inextricably related to timber production, recreational use, and watershed management. Public policy, as outlined by the Multiple-Use Act, implies that wildlife populations be maintained or increased save where they have overreached their land base. Favorable habitat is the key to sustained wildlife abundance; and habitat in turn is a product of the logging and fire history of the forests and of present land management systems. The animal and the forest are directly related. The white-tailed deer, for example, can limit forest reproduction just as silvicultural techniques limit deer numbers and food supply.

Wildlife values are both tangible and intangible. In 1962 Michigan, Minnesota, and Wisconsin together reported 1-3/4 million licensed hunters whose expenditure for licenses alone was approximately \$8.5 million. Assuming that the license represents 10 percent of the cost of pursuing the sport, the sportsman's 1962 expenditures would be about \$85 million.

The importance of observing wildlife to the summer visitor is difficult to quantify in dollars and cents and perhaps should not be so quantified. However, the opportunity to observe wildlife undoubtedly has considerable economic impact.

Despite the obvious and widespread public interest, resources for study of forest wildlife are grossly inadequate. Each of the Lake States have done and are doing excellent work on animal biology and habitat requirements. However, direct work on

habitat has been relatively limited, with emphasis on extensive surveys of the deer range. Little has been done to evaluate the effects of forest management on habitat factors. More factual information should be made available to land managers. The need is immediate!

Major changes have occurred in Lake States forests in the past 20 or 30 years to alter habitat conditions. Natural regrowth and extensive planting, coupled with favorable weather and intensive fire control, have permitted the forest to "grow up." Many acres are covered with pole hardwood stands or young plantations in which crown canopies are closing, browse species are reduced, and forest openings are disappearing (fig. 1). Natural succession and intensified forest management have both worked toward eliminating low-value and intolerant species, with a resulting decrease in diversity of vegetation. The changes in the forest are related to major changes in animal populations and distribution--the greatly reduced population of snowshoe hare today and the shift of the center of abundance of the white-tailed deer southward to the farm fringe.

PROBLEMS OF WILDLIFE SPECIES

The white-tailed deer remains a major factor in habitat deterioration and forest regeneration. As the predominant big-game species, deer sustain the greatest recreational and sportsman interest. However, the winter deer range in much of northern Wisconsin and Michigan is static or continues to deteriorate. The trend toward intensive land management and the increase in wellstocked forest acreage throughout the Lake States necessitates active habitat improvement if the deer herd is to be maintained.

The growing moose population in northeastern Minnesota is already exerting con-



Figure 1.--Left: A portion of an extensive and dense pole stand of northern hardwood with little value as wildlife habitat. Right: A mixture of aspen and birch interspersed with clumps of conifers, brush, and recent cuttings provides a favorable situation for ruffed grouse, white-tailed deer, and other wildlife. The logging road provides hunter access. When seeded, trails like these furnish abundant clover and other herbs for grouse and deer use.

siderable pressure on the forest. This development should be documented and will soon require remedial measures.

Interest in beaver continues although work pointed toward habitat and utilization of beaver, both for fur and impoundment production, has been limited. Beaver, especially on low gradient streams, may seriously reduce the trout populations, while on steeper streams they appear beneficial. Beaver may also destroy swamp conifer stands, essential winter cover for deer. Fire control prevents extensive aspen regeneration and thus reduces beaver food supplies. The beaver-trout-forest relationship is in need of further study.

Bear populations have grown throughout the Lake States, and the bear now receives considerable attention as a game animal. However, bear behavior and habitat requirements are only partially understood. Further study will be profitable both in respect to game management and in relation to manipulation of bear populations near human concentrations.

Interest in game birds, especially ruffed grouse and sharp-tailed grouse is growing. Ruffed grouse have declined somewhat in numbers, and populations do not fluctuate as widely as during the 1930's. The ruffed grouse is the major forest game bird. Its importance warrants research on suitable habitat. The sharp-tailed grouse likes large forest openings and forest border situations; its management involves a special use development. Some direct measures for improvement of ruffed grouse habitat such as trail seeding are being utilized; others, such as clump planting of conifers in pole hardwood stands, should be considered.

RESEARCH NEEDS

A basic problem is the need to maintain the production of wildlife without a major loss in wood production. The importance of wildlife in the Lake States suggests that some loss would be justified if wildlife benefits accrue. There are other problems; for example, the harvest of white-tailed deer is not yet sufficiently

well organized on a scientific basis to be able to balance the herd and the habitat within reasonable limits. Such a balance requires flexibility, which is not yet possible.

An urgent need in habitat planning is knowledge of the habitat effects of commercial forestry practice. Commercial cutting is the chief method of habitat improvement. In general, principles of cover, species preferences, need for open space, etc., are reasonably well understood; but detailed evaluations of wildlife response to silvicultural practices are lacking. Our habitat program considers evaluation of cutting methods as an item of top priority.

Another critical area is the evaluation of habitat improvement practices already in use on National Forests and state lands. Most of these practices are soundly based in theory--for instance the setting aside of existing openings and creation of others where none exist. However, details of procedure and the animal and bird response should be evaluated.

A third major area for habitat research is the study of life histories of common browse species and of other berry- and fruit-producing plants. A very limited amount of work has been done; much more is needed.

Finally, for effective management, suitable routine range evaluation techniques must be perfected and tested.

WORK IN PROGRESS AND PLANNED

Before the Lake States Station habitat project was initiated 2 years ago, some work in wildlife habitat had been done in cooperation with the U.S. Fish and Wildlife Service. A recent study on cutting methods in conifer swamps indicated that strip cutting was the most suitable method for wildlife since it resulted in abundant browse production in the cut strips combined with good cover in the uncut areas. Other studies have explored the amount of browse made available in tree tops cut during logging operations and have used exclosures to document deer influences on forest development.

At present the major effort is being placed on the evaluation of silvicultural systems used in northern hardwoods in relation to their effect on deer habitat. In cooperation with the Wisconsin Conservation Department we have been studying cutting methods in sapling, pole, and small sawtimber stands which, in the uncut condition, represent the poorest wildlife habitat. Any cutting method that increases stand diversity and produces browse which can be consumed without serious damage to forest reproduction is of interest (fig. 2). A deer eats approximately 5 pounds of woody browse per day during the winter period. We have found that browse production varies from as little as 2 pounds to the acre in an uncut stand to 20 pounds in a lightly cut stand and over 150 pounds in an adjoining roadside edge. Strip cutting in northern hardwoods is being investigated and

Figure 2.--Measuring browse production and forest reproduction in a recent heavy cut in northern hardwoods on the Argonne Experimental Forest. The cut left 40 sq. ft. of basal area standing and was made in 1957.



shows some promise as a cutting method that may combine both timber and wildlife values.

We have also begun work in aspen stands, where clear cutting generally produces deer browse in the range of 100-250 pounds per acre (fig. 3). Aspen stands are also important to ruffed grouse. Clonal differences in browse production need investigation.

A cooperative project with the University of Wisconsin this past summer concerned the vegetation of natural openings in northern hardwoods. At the same time the Wisconsin Conservation Department studied deer use of such openings. This is the first step in obtaining a better understanding of the role of forest openings in the wildlife economy and determining the specifications for size, number, and management of such openings.

Another study begun this summer concerns the relation of stem form and size to production of browse. The results may simplify future habitat surveys by providing valid data on actual weight of food produced.

Future plans include a study of winter deer habitat in relation to forest management practices in north central Minnesota in cooperation with the Fish and Wildlife Service and the Minnesota Conservation Department. When funds become available,

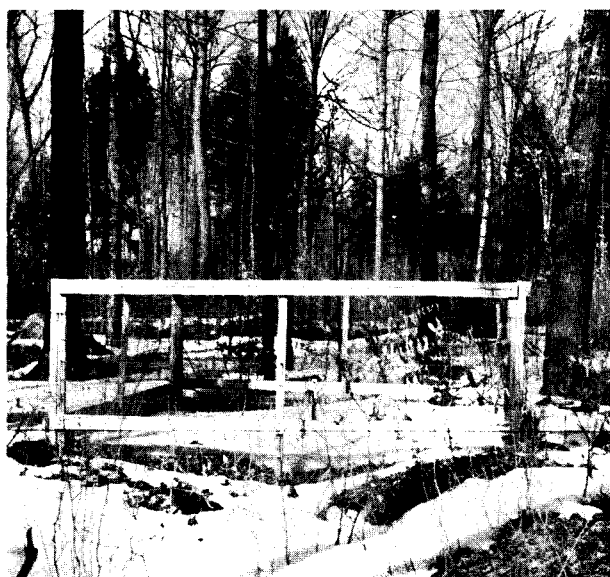


Figure 3.--A small deer enclosure in a recent logging operation on the Argonne Experimental Forest. The enclosure provides an opportunity to study seedling growth without deer browsing.

the wildlife values of red and jack pine plantations in lower Michigan will be analyzed in cooperation with Michigan State University and the Michigan Conservation Department. As soon as professional personnel are added to the staff, work will begin on basic ecology of plants important to wildlife.



U. S. FOREST SERVICE

Establishment and Management of Coniferous Plantations

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

R. F. Wambach, Research Forester,
Plantation Management. Project
located at Cadillac, Mich.

Forest plantations have been established on about 3 million acres in the Lake States and are being added to at the rate of 130,000 acres per year. Nearly two-thirds of the existing pine stands, our most valuable timber type, are the results of planting (table 1). The impact of the large acreages planted in the 1930's is now being strongly felt in the significant contribution of thinnings to our timber supply as well as in watershed, erosion control, wildlife, and aesthetic values.

However, conservative estimates give some 11 million acres of nonstocked and inadequately stocked forest land that should be planted. Our past research and planting effort has been directed toward abandoned fields and barren areas covered with brush and undesirable tree species which present difficult site preparation and release problems. Large areas of lowlands also require planting, but reliable methods are not available for these sites. The need to replace pine being harvested with a new crop and to convert low-quality, low-value timber types to more desirable coniferous stands adds to the complexity and size of the planting job ahead.

Plantation management will consequently be an important forestry activity in the future. In the Lower Peninsula of Michigan alone, an estimated one mil-

lion cords of wood will require harvesting from planted stands to keep them in good growing condition. Although progress has been made on release from competition, thinning, and pruning for red pine on some sites, management prescriptions have to be developed for all sites, several densities of original planting, and for other important plantation species.

Planting must now, more than ever, be justified in relation to other investment alternatives and must compete as one of several alternative land uses. This is in contrast to past work which was basically one of learning how to grow good planting stock and to plant it successfully in the field, for planting was considered good, in and of itself. Research must now find ways to minimize costs, to increase the yield of specific products, and to maximize returns on plantation investments. In addition plantation research must address itself to such new activities as recreation, wildlife, and watershed management.

Past research has resulted in the successful establishment of large acreages of plantations, but the present program is not adequate to meet the anticipated needs of the future. Conditions have and will continue to change; new problems are arising. A greater research effort is necessary.

The following listing of special problem areas will serve to illustrate the scope of the research program needed.

NURSERY

Early research helped to develop basic nursery practices and establish stock standards, and contributed materially to the early success of Lake States planting programs. Currently, however, very little research is being done in nurseries. The one study recently completed examined the possibilities of using supplemental light or longer growing seasons. It was

found that supplemental light used in our local nurseries might effectively eliminate the need for transplanting spruce stock. It was also found that the growth and development of both spruce and pine could be greatly accelerated by growing them in southern latitudes (Florida) with supplemental light. These results are very promising, and they should be tested on a pilot basis. More follow-up work is needed, as is a thorough analysis of

Table 1.--Forest acreage in the Lake States

(1,000's of acres)^{1/}

Land use	Michigan	Wisconsin	Minnesota	Total
Commercial forest land:				
Total	19,121	15,396	17,056	51,573
Coniferous stands				
All	3,761	2,055	5,910	11,726
Pine	1,623	1,014	1,355	3,992
Nonstocked	3,148	2,553	1,855	7,556
Poorly stocked seedling and sapling stands	1,522	911	844	3,277
Recently abandoned crop and pasture land ^{2/}	--	--	--	2,160
Plantations only:				
All species	1,500	1,000	600	3,100
Red, white, and jack pine ^{3/}	--	--	--	2,600

^{1/} Source: Michigan - Lake States Forest Experiment Station, Station Paper 82, 1960.
 Wisconsin - Lake States Forest Experiment Station, Station Paper 90, 1961.
 Minnesota - Unpublished data from recently completed Forest Survey.
 Plantations - See figure 2.

^{2/} Quinney, Dean N. Lakes States Forest Experiment Station, Technical Note 600, 1961. This is an estimate of the area of nonforested farm land that was taken out of production between 1950 and 1960.

^{3/} Author's estimate.

the economic potentials of these new techniques.

Other research needs in the nursery include continuous testing of new fertilizers, pesticides, soil binders, etc. Currently most of this is being done by nursery operators on a trial and error basis. More work should be done on ways to eliminate the need for transplanting in the nursery, an operation that can double or triple the cost of planting stock. Suitable seedling stock probably can be produced with the right combination of spacing, irrigation, fertilization, light, and stock grading.

PLANTING

Early planting research was largely directed towards methods, choice of species, and early survival. More recently some important work on site preparation and initial spacing has been undertaken. But the problems needing study are legion. Planting sites are becoming more difficult, costs are rising rapidly, and new economic pressures have forced us to realize that growth, not survival, is the pertinent measure of planting success.

Better and cheaper site preparation techniques must be developed. Prescribed fire shows promise. We must learn how to identify the more productive sites. Recent research has shown that site quality probably has more impact on financial return than do stocking, rotation length, or any other of the standard silvicultural variables. Planting costs must be reduced. Wider initial spacing would be a big help. Recent findings indicate that this is feasible in red pine, but the effect on product quality and financial yield must be more thoroughly explored. The work should also be expanded to include other species.

EARLY MANAGEMENT

The Lake States Station has a long history of research in thinning, pruning, and release. As a result, we now have a good base of information on which to build. The need now is for studies of a more comprehensive nature. That is, we must consider more variables, and study each over a broader range; we must consider interactions among the variables; and we must try to anticipate future needs rather than concentrate on current problems.

Two studies of this type (one in red pine, one in jack pine) are already underway. These are basic growth and yield studies in which the goal is to determine the effect on growth of such variables as age, site, stand density, and thinning methods. A similar study is needed in spruce, and the same comprehensive approach should be taken in studies of release, tree quality, etc. We must also tackle the more intensive practices like pruning, fertilization, and cultivation. Plantation management is usually capital intensive, and basic information about these various cultural practices is urgently needed. Comprehensive studies of the type proposed here require long periods of time, and the sooner we get started on them, the better.

OTHER USES

Plantations serve many other purposes besides timber production. For seed orchards we must learn how to grow trees with cone production as the goal. For Christmas trees we must learn how to stimulate early growth, control color and shape, and how to plant and grow special exotics like Scotch pine. In this time of multiple use we must study the special problems of producing timber in plantations while simultaneously satisfying needs for recreation, wild-

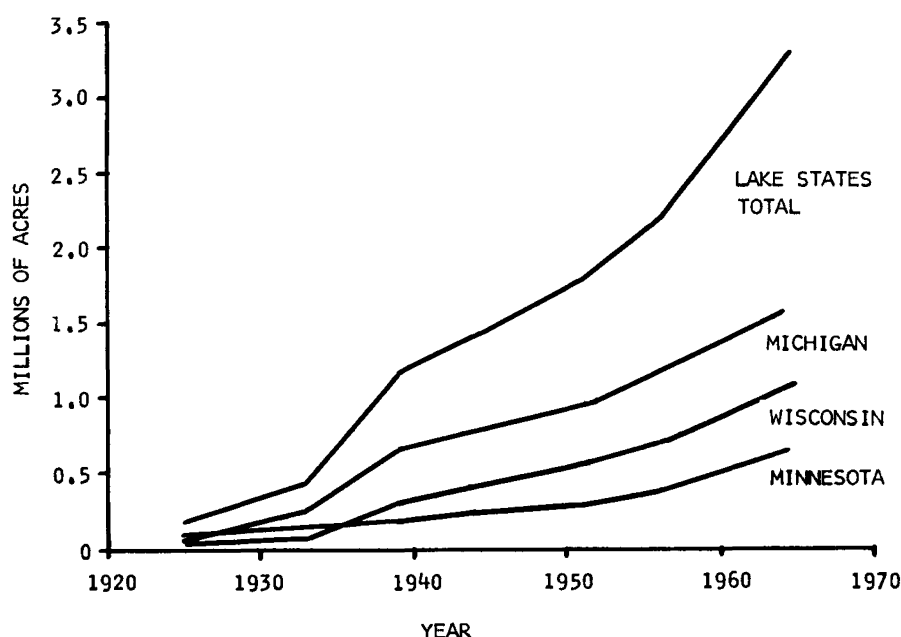
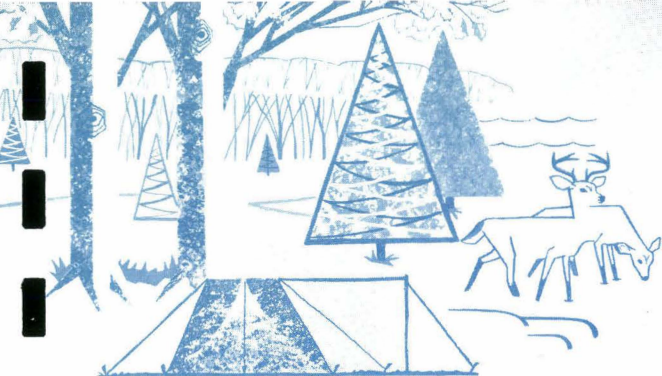


Figure 1.--Area of forest plantations in the Lake States. (Data from U.S.D.A. Technical Bulletin 1010, 1950, and Tree Planters Notes, 1951-1962.)

life and watershed protection.

Plantations are destined to play an important role in the timber economy of the Lake States. With an annual planting investment near \$5 million, it is not hard to explain the need for a research program. Reducing costs a few dollars per acre or increasing yield by a small percentage could be a real contribution. The same is true for research in the management of established plantations. Many of the problems encountered in plantations are different than those in natural stands. Early growth is different because of uni-

form spacing, slow expression of dominance, etc. Plantations are generally better located in reference to markets, and they are managed more intensively. The acreage already in plantations is large and it is increasing rapidly (fig. 1). The owners of these plantations want to know what to expect in the way of growth and yield, how to manipulate the stand to improve overall quality or to produce specialized products, and how to maximize the return on their investment. It is the job of research to help provide the answers.



U. S. FOREST SERVICE

Plantation Insects : Approaches to Control

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Dr. Herbert Ewan, Project Leader,
Seed and Cone Insects.
Project located at Station head-
quarters, St. Paul 1, Minn.

Plantation insects in the Lake States continue as an ever-increasing threat to trees on the large amount of land already planted and on the additional large acreage destined for planting. Experience has shown that these plantings are particularly susceptible to insect epidemics. Two factors are especially conducive to insect damage: Many of the sites have been abused so that the trees already are contending with some adverse conditions; and most plantings are of one species only, which provides ideal conditions for the spread of an epidemic.

Tree planting on a large scale was initiated in the Lake States by the Forest Service during the early 1930's. Insect problems quickly developed and Federal research agencies became responsible for the development of control procedures. Since planting is expected to continue, studies of insect control will continue to be a vital part of the struggle to protect this large investment.

Many species of insects have been found damaging forest plantations in the Lake States. Among the more important species today are: the European pine shoot moth, Saratoga spittlebug, red-headed pine sawfly, white-pine weevil, root collar

weevil, European pine sawfly, white grubs, pitch nodule maker, pine tortoise scale, jack-pine shoot borer, and the Zimmerman pine moth. The first six of these are regularly found in outbreak status nearly every season in various areas.

Each plantation insect damages trees in a distinct way and presents distinct problems of control. Thus, the control technique is determined by the individual insect's behavior, its feeding habits, and its life cycle. Because of the many species of insects, all types of control (chemical, biological, and cultural) have been used successfully.

Following are a few examples of approaches to control of plantation insects in the Lake States.

CHEMICAL CONTROL

We have found that the Saratoga spittlebug, a destructive pest of young red pine plantations, can be safely, economically, and effectively controlled with conventional insecticides. Insecticidal control is a logical choice for the spittlebug for several reasons: The pest spends a good deal of its active life feeding in exposed positions on the twigs of red pine where it can be easily reached with sprays. It has also proven to be susceptible to safe, economical insecticide dosages. Furthermore, since red pine plantations reaching a height of 15 to 20 feet are no longer susceptible to spittle-

bug damage, one or two sprayings during the early life of a plantation are usually sufficient.

In spite of the general success of insecticides against the Saratoga spittlebug, efforts are still being made to find other methods of control--especially by preventing population buildups. Basic biological and ecological studies have revealed that the spittlebug can become epidemic in a plantation only if the ground cover contains a certain complement of alternate hosts to support the immature stages of the pest. Therefore, it is recommended that in establishing new red pine plantations, the highly susceptible sites be avoided. Over a period of time, this recommendation is sure to pay off with increasingly fewer spittlebug-susceptible plantations.

BIOLOGICAL CONTROL

Recent studies have shown that biological control--generally referring to the introduction of parasites, predators, and diseases into insect epidemics--offers great promise for some plantation insects in the Lake States. This is especially true of those introduced from a foreign country and therefore no longer subject to control by its natural enemies.

The European pine shoot moth, ranking as one of the most damaging pests in the Lake States, was accidentally brought into this country sometime before 1914. Here it has proved to be much more destructive than in its native Europe. In contrast to the Saratoga spittlebug, the shoot moth is not readily susceptible to conventional insecticides because it spends most of its active life feeding within the buds of red pine where it cannot be reached with sprays. So far, attempts to control this pest with sprays during the short period when it initially attacks the trees

have yielded discouraging results. Control has been achieved only with abnormally high insecticide dosages. It is natural, therefore, that control studies are turning more and more to noninsecticidal approaches.

A program of collecting and propagating parasites of the European pine shoot moth is being continued. The various species of parasites are reared and released in selected shoot moth-infested plantations (fig. 1).



Figure 1.--Dr. William E. Miller, Project Leader for plantation insects research in the Lake States, releases parasite wasps for suppressing the European pine shoot moth in red pine plantations.

Two Hymenopterous parasites (Orgilus obscurator Nees, and Temelucha interruptor Grav.) are now established and appear to be spreading in

Lower Michigan. It is not expected that one or even a complex of these introduced parasites will bring rapid economic control of the European pine shoot moth. However, their depressing influence on pest populations will make the problem less critical and more amenable to control by other methods.

CULTURAL CONTROL

It has been observed that insects may damage certain plantations less severely than others of the same tree species and age but under different growing conditions. Therefore, studies have been made to develop methods of establishing or maintaining plantations which will render the trees less susceptible to insect damage. These methods of cultural control, frequently very inexpensive and longlasting, can be developed only after careful studies of the population dynamics of the insect. For example, wide differences in the severity of tree damage among plantations infested with the European pine shoot moth were found to be linked to tree vigor--the lower the vigor, the heavier the damage (fig. 2). Thus, a promising method of control is the establishment of plantations only on sites that pro-

mote good tree vigor.

Bottom pruning on infested trees offers another promising method of cultural control. During severe winters, it has been observed that shoot moth larvae hibernating in the exposed, upper portions of the trees were killed by freezing, whereas insects on the lower branches were protected by deep snow. They survived and carried the infestation through to the next season. This suggested bottom pruning as a control method. Results of preliminary studies indicate that winter mortality of the shoot moth is, indeed, higher on the bottom-pruned trees than on the check trees.

Perhaps the most appealing method of cultural control is the planting of genetic strains of trees inherently resistant to insect damage. Natural resistance has occasionally been found in various tree species in the Lake States. A well-known example is the regular occurrence of a small percentage of completely damage-free jack pine trees in stands otherwise wiped out by the pine tortoise scale. Genetic studies specifically designed to search out insect resistance in tree strains will undoubtedly become more and more



Figure 2.--A 9-year-old red pine plantation on sterile subsoil. The trees are of poor vigor and heavily damaged by the European pine shoot moth.

important in the near future.

A small start has already been made on such studies in the Lake States. After the recent discovery of the European pine shoot moth on the West Coast, foresters became concerned about the susceptibility of the important ponderosa pine plantations there. Therefore, a cooperative study was initiated in which three seed sources of ponderosa pine from the West Coast were outplanted in shoot moth-infested areas in Michigan. No clear-cut differences in resistance have been found around the three seed sources to date. However, considering the reward of achieving genetic resistance, intensified studies along this line are fully warranted.

SEED AND CONE INSECTS

Plantations can be threatened by insects even before the trees are put into the ground because of the potential bottleneck created by seed and cone insect attack in seed-production areas. Studies of these pests initiated last year in the Lake States indicate that they can no longer be ignored in the production of forest tree seed. In 10 seed-production areas scattered over the northern Lake States, an average of 65 percent of the 2-year-old red pine cones were found infested with insects. Moreover, in four of the areas, 100 percent of the cones were infested, making seed harvesting impossible.

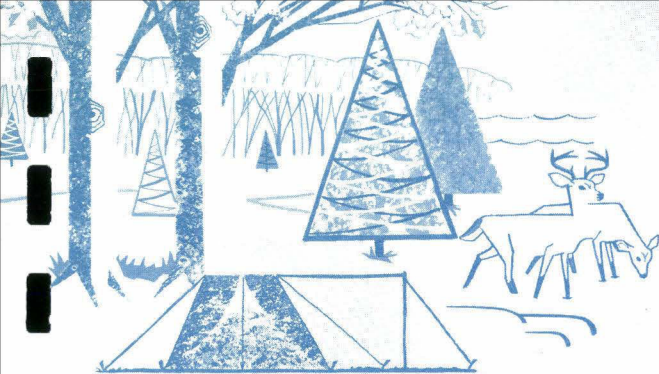
Studies of the seasonal histories of the major species of seed and cone

insects indicate that direct control will be difficult because attack periods overlap and the insects are well concealed during the feeding stages. Systemic insecticides, with their ability to move throughout the tissues of the trees, may be a promising alternative to conventional chemicals.

Most species of seed and cone insects are entirely dependent upon cones for survival. Therefore, an extreme measure for noninsecticidal control would involve the destruction of all cones in an area for several seasons so that the insect populations would die out for lack of food. Another possible cultural control would be the raking and destruction of fallen cones or controlled burning of the duff during the fall to prevent overwintering stages of the insect pests in fallen cones and shoots. These techniques may be considered for seed-production areas where more costly measures can be used than would be practical on insects in natural stands.

IN SUMMARY

These are some of the techniques tried and leads obtained. It is obvious that a broad research approach to plantation insects is required to match the control to the specific insect and host. Hardly a year goes by when a new insect does not become epidemic. This year it is the pine root collar weevil; last year it was the pine tussock moth; a few years ago it was the European pine shoot moth. Each needs careful study before the safest, most economic, and practical control can be recommended.



U. S. FOREST SERVICE

Forest Recreation Research

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Dr. Robert C. Lucas, Project Leader,
Social and Economic Aspects of
Forest Recreation. Project is lo-
cated at Station headquarters,
St. Paul, Minn.

THE RESOURCE MANAGEMENT PROBLEM

The rapidly growing use of America's outdoor recreation resources is so well known now that many people have become immune to visitor statistics, soaring curves, and sky-high projections. Whatever the future brings, it appears certain that the already difficult management decisions will become even harder to make and will need to be made more often.

These decisions will determine the quality of an important part of our national culture. They also will affect the level of income in many regions of the country--regions that must shift from declining types of employment or make painful shifts in population. All of the northern Lake States fall in this category, with fewer jobs in mines, on farms, and in the woods.

Future investments in recreational management will be large. Until very recently, development has lagged behind use. State agencies are beginning to move: Minnesota and Wisconsin both have launched 50-million-dollar programs for resource development, including parks, campgrounds, and scenic drives. Michigan is also drawing up ambitious plans. The commercial recreation industry has lagged; in the Lake States, resort investments in

particular apparently have failed to match the general increase in recreation. The reasons for this are not clear.

Investment decisions will commit money as well as limited land and water areas, and some kinds of poor decisions are hard to correct. Small private developers, characteristically short on capital, seldom have a second chance. Public agencies find it hard to alter established patterns; replacing leased summer home sites with campgrounds or removing resorts to recreate wilderness (both happening in the Lake States) carries high social costs. The decisions are further complicated by the multitude of important suppliers of recreation opportunities, particularly characteristic of the Lake States.

The northern Lake States have substantial recreation potential because of their landscape contrasts and their location near densely populated areas. An abundance of water in a forest setting is within relatively easy reach of the western end of the major urban-industrial region of North America--a region with few natural or man-made lakes. The development of this resource varies from luxury resorts to wilderness canoe country, but little is known about the variation in desires and attitudes of the visitors who use these recreation resources.

POTENTIAL RESEARCH CONTRIBUTIONS

The goal in management of recreation resources is an adequate supply of a wide range of high-quality recreational

opportunities. The supply should be related to the current relative needs for each type of recreation and be responsive to changing needs. It should be provided at a minimum cost, including the cost of reducing or modifying other land uses. Finally, the various suppliers should complement one another.

Research may help by identifying groups of compatible recreation activities within this wide range of opportunities. It may show how nonrecreational uses relate to different types of recreation, and what each opportunity requires in terms of land and water types, size of areas, locations, development, and use controls. Research may also help suppliers achieve flexibility by early identification of trends.

THE STATION PROGRAM

Objectives.--Faced with all of these unanswered questions, the researcher is tempted to try to handle them all, but would probably end up answering none satisfactorily. The Station is, therefore, focusing its efforts on a few important parts of the problem in two recreation projects at St. Paul and one at Ann Arbor.

The St. Paul projects, 3 years old and with two scientists, deal with the social and economic aspects of forest recreation in the northern Lake States. The scientists are now emphasizing two types of influences on the amount and type of participation in forest recreation and the level of visitor satisfaction. The two are:

(1) Resource characteristics--site quality; site location relative to such things as population centers, main roads, and other attractions; the development of the resource facilities; visitor standards for crowding; and compatible uses. This line of research should produce methods of rating sites and establishing development priorities, "social carrying capacities,"

and workable multiple use combinations in different settings.

(2) User characteristics--how choice of recreation and amount of activity relate to occupation, education, income, age, family size and structure, and other measures. This research should contribute to improved use projections, better communication with visitors, estimation of effects of charges, and perhaps some insight into the relative value or importance of various activities to participants.

The Cooperative Recreation Research Unit at Ann Arbor, begun last year, consists of one scientist working with the faculty and students at the University of Michigan, encouraging research on forest recreation and helping develop more qualified research scientists. The scope of research at Ann Arbor will naturally be broader than at St. Paul.

Completed research.--One study has been finished as part of the social-economic project. It dealt with the distribution of use in the Boundary Waters Canoe Area of the Superior National Forest, and how this use related to the capacity of this wilderness lake country. It was a rather broad study, and it helped identify the narrower range of topics on which we are now working. A survey of the entire area was made, and all types of users were interviewed (fig. 1).

We found that there were about twice as many visits as previously estimated by the National Forest staff, but that visits were much shorter than thought earlier. A serious upward bias in any length-of-stay estimates based on unadjusted sample interviews was discovered, and a simple correction technique was devised. Use was very unequally distributed over the canoe country; 10 percent or less of the 50 plus access points had over half of every type of use. The type of user most valuing solitude, the canoeist, was the most concentrated; 57 percent

used one access point. We learned that the unique, carefully controlled logging in a wilderness was successful, and that a more serious wilderness management problem was conflict between different types of recreation--particularly between canoeists and users of motorboats. The canoeist came to the border lakes for "wilderness," and resented the numerous motorboats, which quickly destroyed his wilderness. Wilderness was only a secondary attraction for boaters and they saw a much larger area as "wilderness" than did the canoeists. This suggests that careful zoning might reduce the conflict without discriminating against motorboaters.

Current research.--Analysis is in progress on two studies based on the Lower Michigan National Forests. One deals with resource characteristics and the other with user characteristics. Preliminary work suggests that visitors rate resource quality much higher than the administrators did in a recent inventory. It seems now that beach quality and distance from main roads outweigh other factors in producing heavy use. Michigan National Forest campers rank lower in occupation, education, and income than people attracted to the northeastern Minnesota wilderness, although Michigan campers are still above average. National trends suggest that the kinds of peo-



Figure 1.--Almost 300 groups of visitors to the Boundary Waters Canoe Area and adjacent parts of the Superior National Forest were interviewed at length about themselves, their activities, and their ideas. Canoeists, car and boat campers, resort guests, and people using private cabins were all sampled around the entire canoe country in 1960 and 1961.

ple choosing the wilder area are increasing faster than those using the more developed region.

At Ann Arbor, three cooperative studies deal with landowner attitudes toward Federal land acquisition for recreation, economic models for choosing locations for recreational developments, and hunting pressure on public compared to private land.

Future research.--The two current lines of research will be continued

and expanded to cover other types of areas and visitors, including private commercial recreation. The substitution relations between different kinds of camping (simple and more elaborate) and between camping and resorts will be investigated. Emphasis will be placed on finding and testing methods of integrating the use of public and private developments through exchange of information and publicity. Studies to devise methods for measuring social carrying capacities will be extended to areas other than the canoe country.



U. S. FOREST SERVICE

Forest Products Marketing Research

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Dr. Dean N. Quinney, Project Leader,
Forest Products Marketing Research.
Project located at Duluth, Minn.

Station's marketing research efforts will not be limited to the northern Lake States alone, it seems obvious that here is where the priority effort should be concentrated.

THE PROBLEM AND THE SETTING

The northern Lake States is a land of lakes and forests. The forests, covering three-fourths of the land area, are mainly second-growth stands of aspen, oak, northern hardwoods, pine, spruce, and balsam fir. The northern Lake States also is an area with serious economic problems--problems of unemployment, of underemployment, of blighted communities, and of lack of opportunities for its young people.

Farming never achieved a major land use status in the Northern Lake States and recently has declined drastically. Economic conditions have been depressed in many areas for the past 30 to 40 years. Unemployment averaging 10 percent or more of the labor force (twice the national average) is common. Mining, a major activity in several places, has materially declined as a source of employment. The population in the 80-some northern counties of Michigan, Wisconsin, and Minnesota has increased by only 11 percent in the last 40 years, while that in the southern counties has more than doubled. The area's most capable young people typically are forced to migrate elsewhere to seek employment.

Providing new employment and increased economic opportunities is the number one problem. Although the

A greater economic use of the region's abundant forests would help. In many areas large increases in the annual harvests could be made if markets were available. The current lack of markets not only limits present economic growth but also has serious implications for the future. Species such as aspen, paper birch, jack pine, and balsam fir do not "store on the stump." If not harvested when mature, stands are apt to deteriorate. Better markets now would permit better forestry--necessary harvest cuts, stand conversion when appropriate, commercial thinnings, etc. What the Lake States forests will look like in the year 2000--composition and quality of timber--will depend largely upon the silvicultural practices of the 1960's and 1970's.

PRESENT RESEARCH PROGRAM

In 1962 the Station's marketing research project was reorganized and transferred from Headquarters at St. Paul to a new location on the University of Minnesota Duluth Campus. This brought the researchers to the problem area and provided a closer working relationship with the National Forests, State agencies, and forest industries located there. The Duluth Office is staffed by three specialists in forest products marketing.

At this same time the major emphasis

in marketing research was placed upon development of new or expanded markets for forest products and also upon improving current marketing practices.

Although studies from the Duluth Office will be made in all parts of the northern Lake States (and when necessary in southern counties as well), the initial project is contained in a five-county area centered at Duluth. This area, encompassing all of the Superior National Forest, has some of the largest volumes of available, but at present unmarketable, timber. The Project staff is undertaking a comprehensive approach to market development in the five-county block.

The overall study includes description and analysis of the timber resource, economic, and marketing factors which would influence the expansion of wood-using industries:

1. An intensive analysis of the timber resource itself.
2. A study of the labor supply and potential.
3. An analysis of the water resource in respect to specific sites.
4. A study of the transportation network and the prevailing transportation costs.
5. An examination of certain institutional influences (taxes, land ownership patterns, etc.).
6. An analysis of trends in the national and regional market picture for wood products that could be manufactured from the area's timber resources.

As the study is a new departure in research for the Station's marketing staff, it is a prototype for other studies in other areas of the northern Lake States. Much of the data on inter-regional competitive aspects--i.e., labor efficiency and costs in

the Lake States as compared to other regions of the country, transportation costs to Midwestern markets from area plants as compared to similar ones located in other regions, etc.--will be meaningful for analyses involving other locations in the Lake States and will have a usefulness beyond this initial study.

This five-county study has been underway since the summer of 1962, and much of the necessary data have been collected. Preliminary results have been published on overseas shipment of wood and wood products via the St. Lawrence Seaway (a seemingly unexplored research area), and the labor supply and capabilities. A manuscript on the water resources and possible plant locations has been completed and is now being reviewed. Another manuscript on transportation is being prepared. An analysis of local wood markets in the Duluth-Superior metropolitan area (population about 180,000) will be started within the next few weeks. In addition, informal studies have turned up some apparently promising leads to expanded markets for dimension stock. All of this material, together with other data not specifically mentioned, will be combined in a final comprehensive report including an analysis of the area's advantages and disadvantages and suggestions for increasing the profitable utilization and marketing of the timber resource.

In addition to these specific studies the Station's marketing research staff have taken part in many efforts in the Rural Area Development (RAD), and Area Redevelopment (ARA) programs. We have helped county groups to prepare their Overall Economic Development Plans (O.E.D.P.); reviewed and commented on proposals for ARA-financed studies of wood products manufacture, and provided data to private consulting firms who have contracted to do these studies. We have maintained close liaison and cooperated with various chambers of commerce, local industrial development associations, and other

State and county groups who are promoting economic developments. This work takes time but is necessary for the success of the overall program.

FUTURE MARKETS FOR LAKE STATES WOOD PRODUCTS

The forests of the Lake States are adjacent to the Nation's industrial heartland--nearly 25 percent of the country's population and a slightly larger share of its economic and industrial activity occurs within a 500-mile radius (fig. 1). The industrialized portions of the three Lake States themselves, together with the

adjacent States of North and South Dakota, Ohio, Indiana, Illinois, and Iowa, comprise the prime market areas for Lake States wood and wood products.

What type of an economic area is this 9-State market? In 1960 these 9 States had a total population of 43,709,000, a little more than 24 percent of the national total. In 1958 the 9-State area had close to 24 percent of the Nation's manufacturing establishments, employed 29 percent of the total engaged in manufacturing, and contributed almost 29 percent (39.4 billion dollars) to that portion of the Gross National Product attribut-

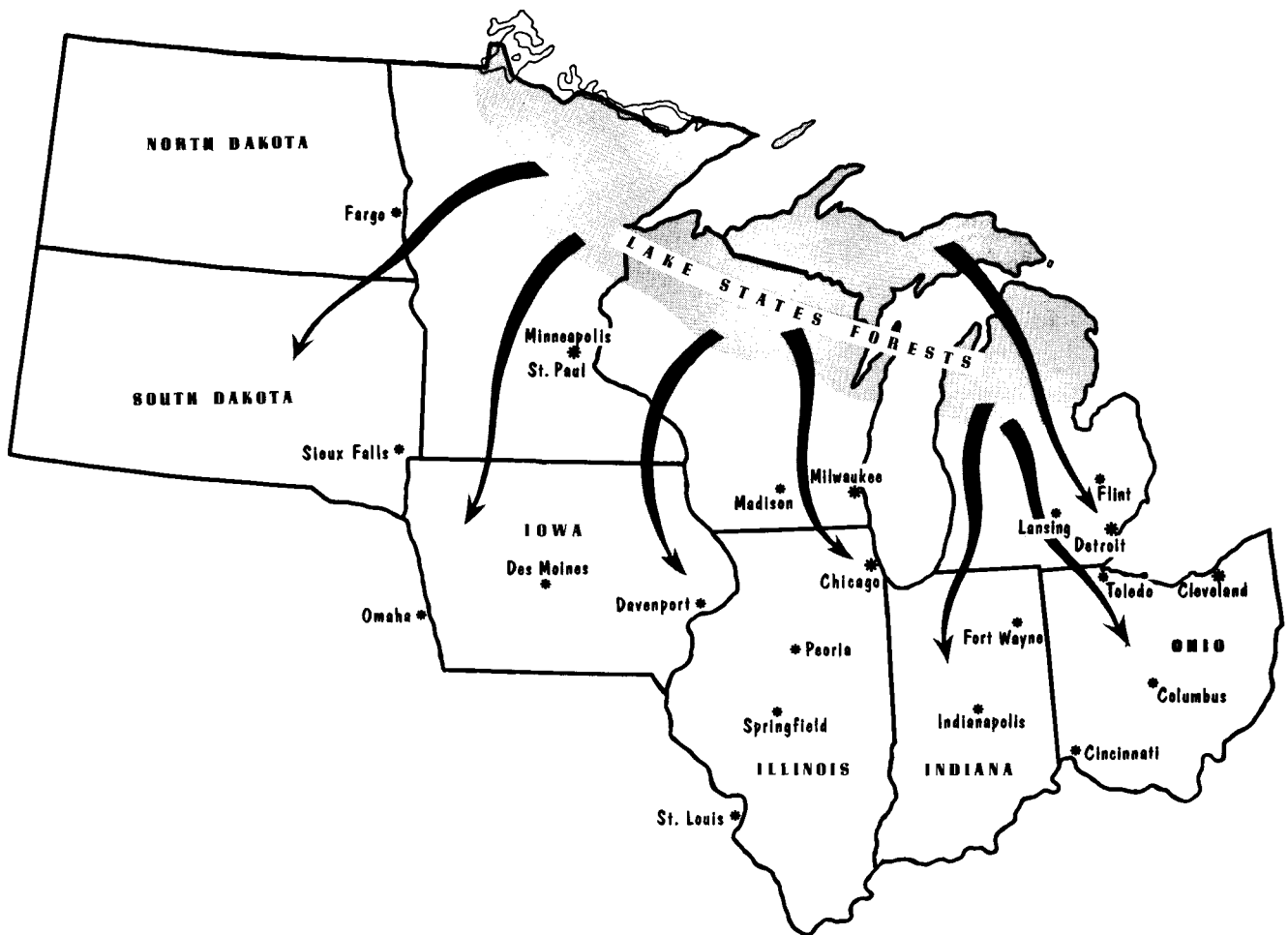


Figure 1.--Industrialized portions of the Lake States and adjacent States are prime market areas for Lake States wood and wood products.

ed to value added through manufacturing.

And what of this market area in the future? Census of Population projections estimate that the 9-State area may have a total population of 57,810,000 in 1976 and 88,195,000 in the year 2000. This represents an increase in population of this potential market area by nearly one-third (32 percent) by 1976, and by more than 100 percent by the year 2000. So, although the spectacular increases in consumer population in certain areas of the Southwest and elsewhere have overshadowed growth in other sections, the highly industrial Midwest seems to have a bright future. And this future can have definite implications to our management, harvesting, and marketing

of wood products from the forests of the Lake States.

SUMMARY

Wood, labor, water, transportation, and a probable expansion in adjacent markets--these are some of the factors which must be considered in analyzing the role of timber resources in the northern Lake States' economic future. Stated broadly, the Lake States Forest Experiment Station's objective in marketing research is to identify, analyze, and suggest remedies for forest products marketing problems so as to increase employment opportunities and help to provide for the long-term economic and social well-being of the Region's population.



U. S. FOREST SERVICE

Lake States Fire Research

LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

John H. Dieterich, Project Leader,
Forest Fire Research. Located at
Station Headquarters, St. Paul, Minn.

FIRE HISTORY AND PROJECT BACKGROUND

Thirty years ago the Lake States experienced their last "old-fashioned" fire year. During the spring, summer, and fall of 1933, 12,093 fires burned nearly a million acres of protected wild land. The rapid decrease in both

number of fires and area burned during the remainder of the 1930's (fig. 1) may be partially explained by a combination of circumstances: People became more fire conscious, protection agencies became better trained and equipped, and the fuel situation changed with respect to high-hazard areas.

By 1940 the number of fires and area burned reached a certain degree of stabilization and except for minor fluctuations have remained remarkably steady.

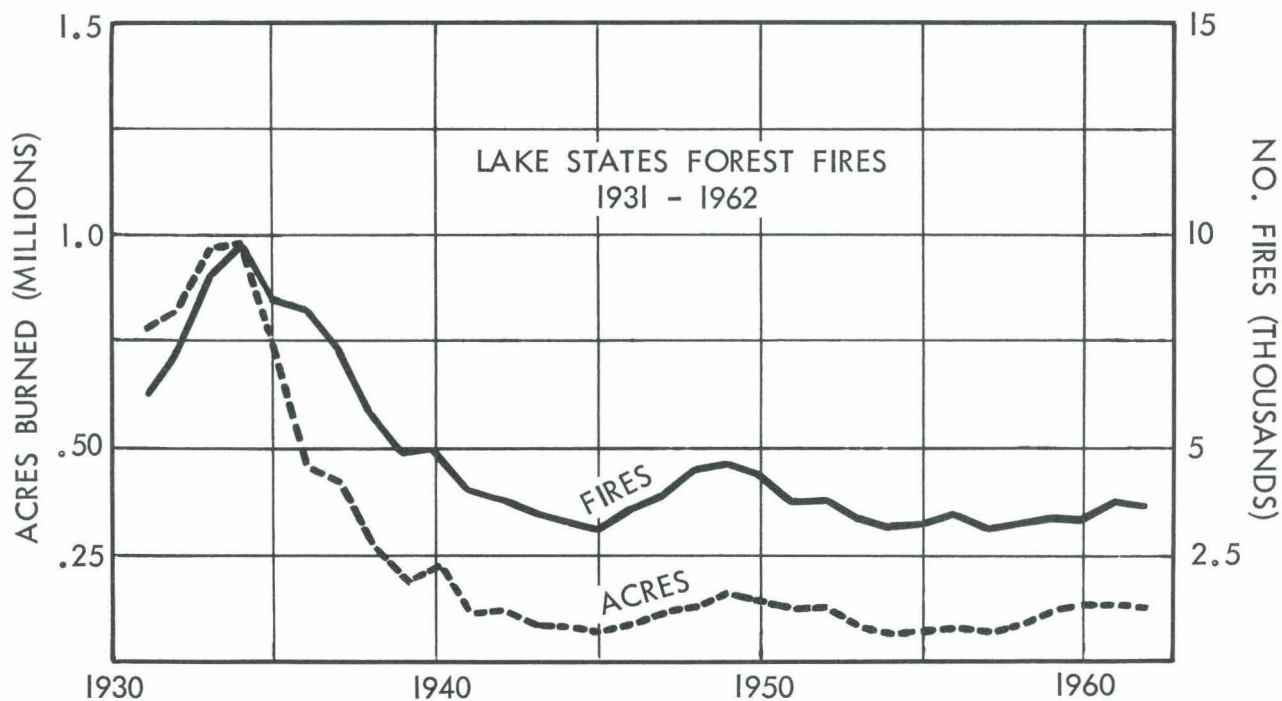


Figure 1.--Lake States forest fires, 1931-1962, 5-year averages.

Who is responsible for the fires that occur in Lake States forested areas? The major causes of fires during the 9 years between 1954 and 1962 are shown below:

<u>Cause</u>	<u>Number of fires</u>	<u>Percent of total</u>
Debris burning	9,522	31.1
Smokers	6,506	21.3
Miscellaneous ^{1/}	6,187	20.2
Railroad	3,931	12.8
Incendiary	1,941	6.3
Campers	1,569	5.2
Lightning	649	2.2
Lumbering	275	.9
	<u>30,581</u>	<u>100.0</u>

The data indicate conclusively that debris burners and smokers are the major contributors to the overall incidence of fires. Lumbering, lightning, and campers, while important in some other parts of the country, combine to produce only about 8 percent of our fires--a good record.

During the past 30 to 40 years the fuel situation in the Lake States has undergone some major changes. We have gone from a cutting era in the twenties to an era of growing trees in the late thirties and the forties and back to a cutting trend during the past few years. This cutting trend is likely to continue.

About 3 million acres of plantations have been established in past decades, and more are being planted each year. Early plantings are already being harvested. Thus once again large areas of high-hazard coniferous timber and large volumes of logging slash are present.

Fire research has been a part of the Lake States program for nearly 40 years. Early work was directed toward gaining a better understanding of fire

1/ Includes fires not readily identifiable with one of the above categories.

problems throughout the three-state area. A forest fire danger rating system was developed to help evaluate the effectiveness of fire control organizations and provide a basis for prevention and suppression activity. In 1960 the fire project was given support through additional funds; since that time it has grown to include research studies in many different areas. There are presently two full-time research foresters on fire research project work in Michigan, Minnesota, and Wisconsin. This work has as its goal the development and improvement of fire control systems that are particularly adapted to protection of Lake States conifer types and plantations. Specifically the research is directed toward (1) how to prevent, (2) how to control, and (3) how to use fire.

CURRENT RESEARCH

Five of the current studies are directly associated with forest fuel characteristics, an important key to more efficient fire control and a better understanding of fire behavior. Three of these studies are attempting to define physical changes in fuel structure; and two studies are measuring fuel volume (weight per unit area) as it is affected by stand density, age, and site. These studies are listed and briefly described below:

1. Fire weather and litter moisture.--Changes in moisture content of surface fuels in relation to changing fire weather are being studied to better understand ignition and fire spread. (FIRE CONTROL AND FIRE USE.)

2. Green crown moisture.--This study attempts to correlate green crown moisture with past weather conditions in order to better predict critical periods of low crown moisture content. (FIRE CONTROL.)

3. Slash deterioration (fig. 2).--This study will attempt to define the types of slash that remain critical from



Figure 2.--Three-year old logging slash is still a hazardous fuel.

a fire standpoint and the length of time it takes for slash to deteriorate to a relatively safe condition. (FIRE CONTROL.)

4. Crown weight determination.-- Information is being obtained on the available fuel (weight of tree crowns) in plantations that vary by age, species, site, and spacing. (FIRE CONTROL.)

5. Litter or surface fuel weights.-- This is a continuing study to determine the amount of dead combustible material that accumulates under various plantation stands. (FIRE CONTROL AND FIRE USE.)

In addition to these five studies efforts are being directed toward three important areas of applied research; the objective is to provide for more effective prevention, control, and use of fire. These studies are described below:

1. Chemical firebreak maintenance (fig. 3).--Firebreaks are an important means of supplemental protection in the Lake States. Control agencies frequently rely on breaks adjacent to plantations and high-risk roadside areas to stop small fires before they

Figure 3.--Soil sterilants show promise in maintaining vegetation-free firebreaks.



have a chance to run into more critical fuels. In this study, soil sterilants are being applied on various cover and soil types under simulated firebreak conditions to determine their effectiveness in keeping the break free of vegetation. Results are encouraging, costs are not unreasonable, and good control has been achieved for as long as four growing seasons. (FIRE CONTROL.)

2. Fire danger rating.--Improving and perfecting the systems of rating forest fire danger or burning conditions is a continuous project both locally and nationwide. Next year (1964) a Unified National System of Forest Fire Danger Rating will be introduced and used by the National Forest Fire Protection organizations. We hope that the State Protection Agencies will accept this new system, too, and will put it into operation as soon as possible. Our job in research has been to develop the system and to help provide the interpretive material so important in converting from one system to another. The Unified National System has a great deal to offer both technically for our local use and from the standpoint of national uniformity. It will provide a sound basis for fire control expenditures and will make it possible to compare fire weather in the Lake States with fire weather in other parts of the country. (FIRE PREVENTION AND CONTROL.)

3. Prescribed burning.--Prescribed burning has a definite place in Lake States forestry and land management,

but it has not received wide acceptance in the past. The reason stems from the fact that prescribed burning is a complex technical science and requires an organized concentrated effort to establish where, when, and under what conditions burning can best be done to realize specific objectives. It is currently being used for hazard reduction, site preparation, type conversion, and improvement of wildlife habitat. Sometimes it is used effectively, other times the results are not nearly so satisfactory.

Our research in prescribed burning is directed toward finding out why some burns are successful while others are not and attempting to identify the conditions under which successful burns can be completed. Season of the year is recognized as being an important variable. Equally important are current and cumulative weather, fuel moisture content, and fuel volume. These four factors operating independently and in combination make prescribed burning a highly technical practice. (FIRE USE.)

FUTURE RESEARCH

If the fire research project continues to expand, we hope to begin a substantial program in fire prevention research. This work will be aimed at specific areas where man-caused fires contribute most to area burned. Also more effort will be directed toward prescribed burning research--particularly the techniques of doing the job under various combinations of fuel and weather.



U. S. FOREST SERVICE

The Forest Genetics Program

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

Dr. Hans Nienstaedt, Project Leader,
Genetics of Northern Forest Trees.
Located at the Institute of Forest
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Twenty-five million acres of forest land are in need of planting in the northern section of the United States, and only about one-third million acres are planted annually. Obviously, therefore, the planting program must be increased in the coming years.

The task will not be completed when the plantable area is in acceptable cover. In addition, to meet coming demands the intensity of forest management of natural stands must be steadily increased. Without doubt, this will mean less reliance on natural regeneration of such stands in the future and an ever-increasing use of planting. The demand for reliable planting stock will therefore continue indefinitely.

Planting alone probably will not be enough to meet future demands; greater volume production of higher quality products will be necessary. This can only be accomplished if new, faster growing, high-quality strains are developed.

The Lake States Forest Experiment Station's Institute of Forest Genetics has devoted its entire research effort since 1955 to the accumulation of basic information essential for the selection and breeding of such improved strains.

From an unpretentious beginning with

two research men and one forestry aid housed in temporary offices in Rhinelander and St. Paul, the Institute now is staffed with six researchers, three aids, and two clerks. Facilities include 10,000 square feet in laboratory and office space, a 2,500-square-foot greenhouse, and 3,200 square feet in coldframe structures. The adjoining Hugo Sauer Nursery, owned by the Forest Service and operated by the Wisconsin Conservation Department, provides excellent nursery facilities for this research program.

Currently, the genetics program at the Institute is being developed along four main lines of research:

1. Studies of the genetics of spruce and other conifers.
2. Studies of the genetics of the genus birch.
3. Studies of radiation effects on conifers.
4. Basic studies of the physiology of root initiation and development of cuttings.

SOME ACCOMPLISHMENTS TO DATE

The spruce program has been underway since 1955. Studies of genetic variation have been the primary undertaking, with more than 80 provenances now fieldplanted in 13 test plots from North Dakota to Maine. Three separate studies are involved (fig. 1). Study objectives are to: (1) Elucidate the evolution and migration history of white spruce; (2) determine whether or not adaptive variants can evolve as a result of strong climatic



Figure 1.--A portion of the Lake States Forest Experiment Station's Institute of Forest Genetics research nursery. Shown is one of three studies of seed source variation in white spruce. Twenty-nine seed sources are being studied in replicated tests. The nursery is operated by the Wisconsin Conservation Department.

gradients operating over short geographic distances; and (3) delineate zones within which seed can be moved without loss of production.

Seed has been accumulated from more than 300 individual spruce trees, some particularly selected for quality, others for extreme characteristics. More than 75 of the trees have been cloned. All this material is part of a study of heritability in spruce. The degree of genetic control of economically important characteristics will be determined and the relative efficiency of wind-pollinated progeny tests, clonal tests, and partial diallelic tests evaluated. Some early results from clonal tests indicate fairly rigid control of needle length and needle color. Most important of all, however, is the strong genetic control of flushing time and therefore degree of spring frost injury. Damage varies from 100-percent bud kill on early flushing selections to no damage whatever on the best late flushing clones. Clearly, the development of a true-breeding late-flushing type could be of great value. Such a breeding program is now on the way (fig. 2).

A picetum or spruce arboretum has been established at Rhinelander and is being expanded from year to year. The collection now numbers 25 of the 30 to

40^{1/} known spruce species; very likely it is the most complete spruce collection in the world. The material will be used to expand the study of crossability in the genus, i.e., determine what hybrid combinations between species are possible. This is information of both practical and theoretical value. About 40 hybrid combinations have been tried at Rhinelander, and hybrids of about 10 combinations are being tested in replicated tests.

Spruce grafting techniques have been improved, and reliable methods for fall greenhouse grafting and July field grafting developed. This has extended the regular grafting season considerably.

The second year of the birch breeding program has been completed. Techniques for greenhouse grafting and pollination have been modified to the conditions in the local greenhouse and climate. Cross- and self-compatibility have been tested for individuals of three native species. Diallelic crosses of selected individuals representing several different seed origins have been set up and partially completed. Such cross pollinations

^{1/} The exact number is not known since the taxonomic status of some species is controversial.

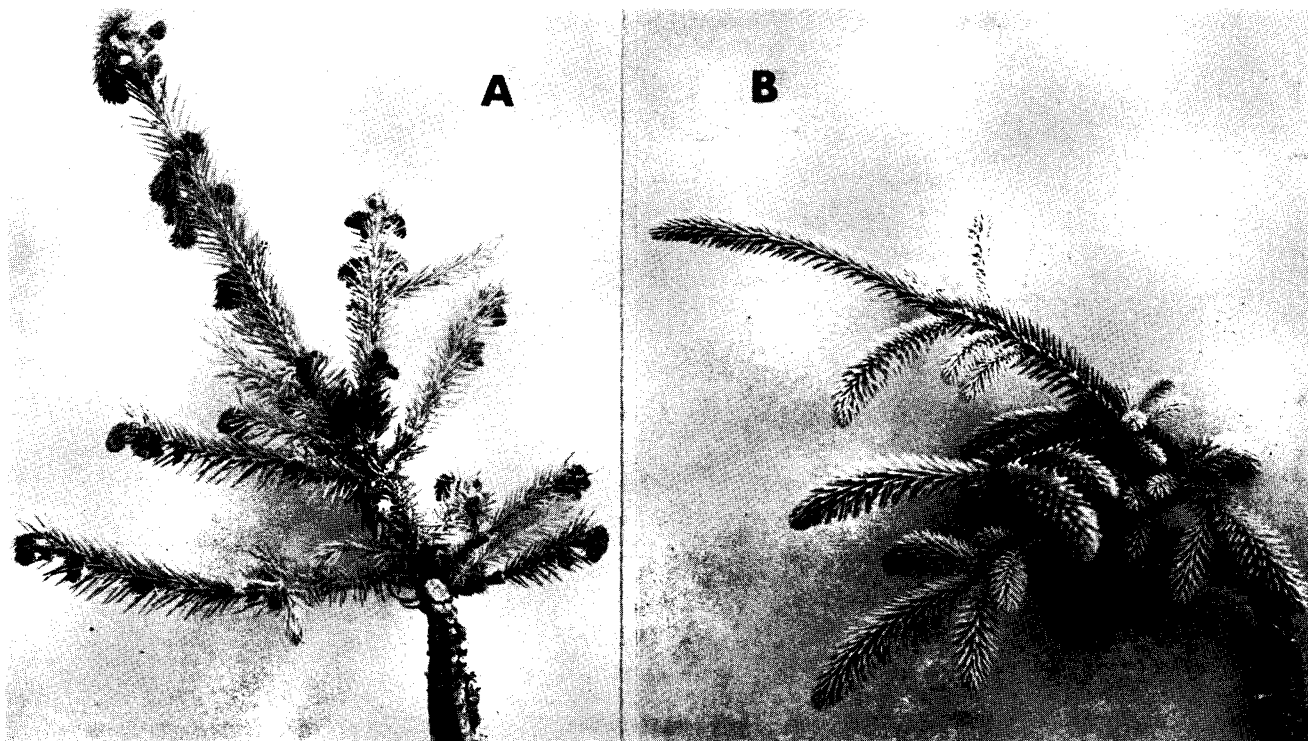


Figure 2.--Frost resistance test of white spruce clones.
 A, susceptible graft. B, resistant graft. Material
 grafted April 1960; photos 6/14/63.



Figure 3.--Establishing final grade on the radiation site,
 an Accelerated Public Works Project.

will be repeated on a larger scale in coming years and should yield information regarding this very important breeding method.

A study of racial variation in yellow birch is now being planned and will be initiated the fall of 1963.

Research on radiation effects will not reach full proportions until radiation facilities are completed at Rhineland. The 6-acre field and the surrounding mile of protective fencing are now being constructed (fig. 3). The fabrication of the source itself, the casing, elevation mechanism, and control house await financing. When completed, a fully automatic 1500-curie cesium¹³⁷ source will be available for studies of the effects of chronic radiation on conifers--the most radiation-sensitive group of plants--and broadleaf trees.

Some studies have already been started, using the gamma radiation field at Brookhaven National Laboratory. Cone and embryo development are being studied on jack pine trees planted in the field at different levels of radiation. In another study, irradiated white spruce pollen has

been used for the production of five large white spruce progenies. The study tests the theory that greater genetic diversity and therefore a greater amount of growth can be obtained through the use of irradiated pollen. If this is possible, it would be a very simple method of improvement.

More than 1200 pollinations were made in 1963 on two populations of jack pine: one derived from X-irradiated seed, the other from a standard seed lot. The study is an effort to determine mutation rates in jack pine and make a general survey of mutation types in the species. Wind-pollinated progenies of the two populations have already been grown and many mutant types selected. These mutants are now being studied cytologically.

The basic physiology of root initiation is still in the earliest phases of study. During one short year of work, techniques for the growing of white spruce meristems in a sterile synthetic medium have been developed. This problem solved, studies of the controlling chemical factors are now being initiated.



U. S. FOREST SERVICE

Physiology of Wood Formation

• LAKE STATES FOREST EXPERIMENT STATION • U. S. DEPARTMENT OF AGRICULTURE

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The anatomical and technological aspects of wood quality have been a subject of investigation for many years. During this time, certain physiological problems relating to wood quality have also been sporadically studied by a few interested investigators. But these researches have never been sufficiently coordinated to bring both tree growth and wood quality into proper perspective. In recent years, however, greater emphasis has been placed on the economic aspects of wood quality and, as a result, demands have been made for a better understanding of the fundamental physiology of wood formation in trees.

A principal goal of the Pioneer Research Unit at the Institute of Forest Genetics is to formulate a concept of wood quality that will demonstrate not only how the wood and wood fibre characteristics are related developmentally, but also how environment and conditions of growth can alter these developmental processes. In order to formulate such a concept, the Unit has: (1) Comprehensively reviewed the vast and largely uncoordinated literature on wood quality and, (2) established and conducted research

^{1/} This is the second Pioneering Research Unit that was established by the Forest Service. Its field of research is the topic named in the title of this article.

investigations based on the knowledge gained from such reviews.

Although extremely time-consuming, literature reviews covering the numerous facets of both wood quality and tree growth have enabled us to re-evaluate and to reinterpret many of the older hypotheses regarding wood formation and to propose new ones where none previously existed. These hypotheses are broad, general views of a problem that provide a frame of reference for future research. Such an approach to research, encompassing several interrelated hypotheses simultaneously, permits an integrated study of the dynamics of wood formation without unnecessary duplication of previous efforts.

Research to date indicates that essentially all wood formation is governed by the size and distribution of the live crown on the bole in addition to the vigor and productive efficiency of the crown. This implies that the vegetative organs of the crown regulate the amount and distribution of wood growth on the stem and also the nature and structure of the individual cellular elements comprising the wood. Since crown attributes are constantly changing with time, the structure of the wood produced will likewise change. These changes in wood structure associated with a developing crown account for the positional variations in wood quality with age on a cross-section and with height in a tree. Various stages in the seasonal cycle of vegetative crown development can also be correlated with the type of cells produced in the formation of the growth ring. Thus, the transition from

earlywood to latewood coincides with the approximate cessation of terminal elongation and setting of the new bud.

By recognizing the role of the crown in regulating wood formation, it has been possible to experimentally test basic hypotheses of the physiology of tracheid development. For example, tracheid diameter appears to be regulated by an auxin stimulus originating in the actively growing regions of the crown. Large-diameter tracheids will be produced whenever shoot or needle growth is active and auxin synthesis is high, whereas narrow-diameter tracheids, such as those found in latewood, will occur whenever the supply of auxin is reduced in some part of the stem. In a quite different manner, the secondary cell wall thickening, typical of latewood tracheids, is determined by net assimilation and the level of photosynthesis. Therefore, the decrease in tracheid diameter and increase in wall thickness of latewood tracheids, although occurring simultaneously in normal latewood

development, are determined by independent physiological processes. The fact that these processes are independent can be demonstrated by controlled-growth experiments (fig. 1).

Current research is aimed at exploring more basic phases of these growth processes. We are interested in determining how the crown can regulate tracheid development at points far removed in the lower bole. For this, we intend to use radioactive tracers in combination with controlled-growth conditions. These techniques will permit us to study both the regulation of tracheid diameter and secondary wall thickness. For the latter, we are interested not only in the origin and the translocation of the photosynthates contributing to wall thickening, but also in the incorporation of these materials into the different chemical constituents of the cell wall. By these and other experiments, we hope eventually to contribute some knowledge to our overall goal of a unifying concept of wood formation.

September 1963

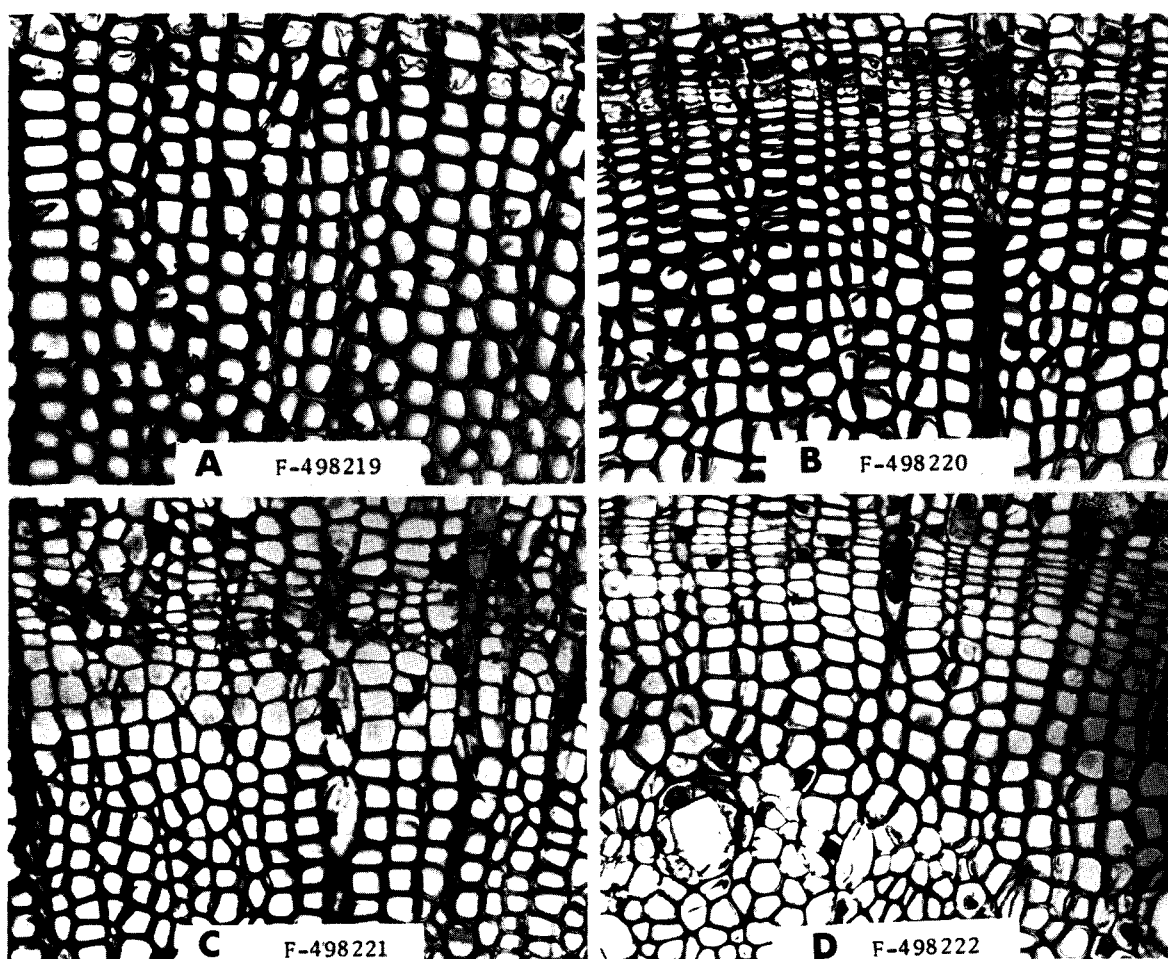


Figure 1.--Tracheid diameter and wall thickness can be altered independently for limited periods by deliberate regulation of growth. Under favorable conditions, tracheids with normal wall thickness are produced, but radial diameter varies with photoperiodic exposure:

- (A) Long days--18 hours daylight.
- (B) Short days--8 hours daylight.

The other two photos illustrate the influence of current-year internode defoliation. This causes an immediate decrease in tracheid wall thickness, but radial diameter again varies with photoperiodic exposure and activity of the terminal bud:

- (C) Long days--terminal bud flushing.
- (D) Short days--terminal bud dormant.

Although nuclei are visible in the differentiating tracheids of D, these cells would eventually mature with little further increase in either diameter or wall thickness.